INSTRUMENTS

THE MAGAZINE OF MEASUREMENT and CONTROL

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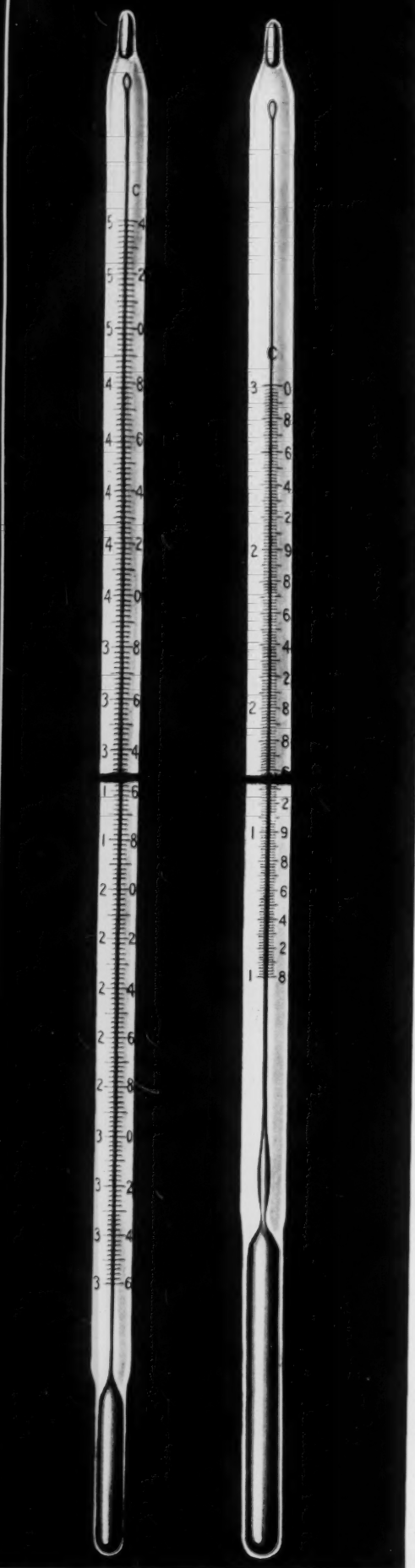
JULY
1937

NUMBER 7



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Illustrated here, are two of the many plates showing TAG Etched Stem Laboratory Thermometers which appear in the new TAG Catalog No. 1100-I. We would like to send you a copy of this latest catalog, for it will prove of valuable assistance to you. In addition to a complete listing of laboratory thermometers and hydrometers, you will find other interesting and instructive information, including Fahrenheit, Centigrade, and Beaume Specific Gravity Conversion Tables, as well as useful data relating to the use of these important instruments.

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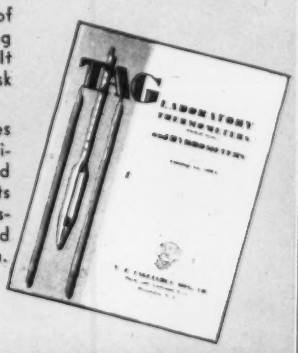

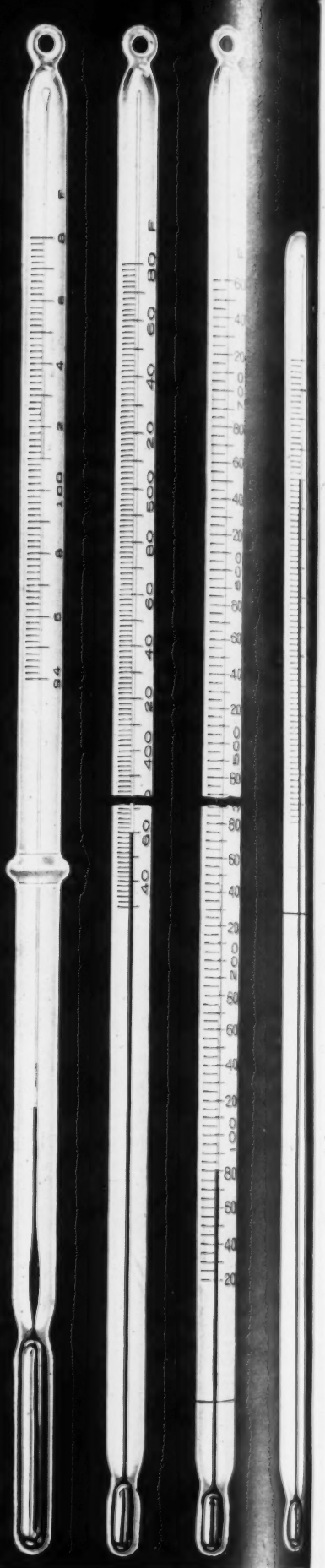

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All of these advantages make Foxboro Thermometers the most economical from every point of view. Even the purchase price is low. Write for Bulletin 148-4—it gives full details . . . The Foxboro Company, 46 Neponset Ave., Foxboro, Massachusetts, U. S. A. . . . Branch offices in 25 Principal Cities.

FOXBORO

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Certified **DIAL-TYPE THERMOMETERS**

RESPONSE·ACCURACY

INSTRUMENTS The Magazine o MEASUREMENT and CONTROL

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INSTRUMENTS The Magazine of MEASUREMENT and CONTROL

M. F. BEHAR
EDITOR

IN THIS ISSUE

In last month's "New Instruments" Department we ran a news item describing a new line of indicating electrical instruments which can be plugged into *ad hoc* sockets, like the plug-in watthour meters brought out three or four years ago. The underlying idea, however, deserves more than a news item, and so we give two pages to Douglass Young, who is chiefly responsible for the embodiment of this new method.

From time to time it is our pleasure to accept for publication the descriptions of various new or unusual lubrication testing methods. Another appears this month, by Kyropoulos and Shobert.

Professor Williams quotes at length, in his instalment, from the groundbreaking discussion of scratch hardness by Mohs, published in 1822 but ever-modern in its methodology.

Ralph Batcher now broaches an entirely new subject in his cathode-ray oscillography serial: sources of error.

THE FRONT COVER

Three months ago our Readers at Work Department was invaded most pleasantly by a group of women readers at the Good Housekeeping Institute, who are as precision-minded as old man Mike Roueter himself. Now the fair sex is invading our front cover! Actually, however, it's a case of industrial instrumentation invading most efficiently the beauty-parlor field. Specifically it shows how Delmo Mfg. Co. permanent-wave machines are equipped with Tagliabue photoelectrically-balanced potentiometric pyrometers. The thermocouples are imbedded in the curlers so as not to harm a hair of Milady's fair head.

Automaticity Makes Jobs

IGNORING the wise counsels and factual expositions of engineers, industrialists and economists who *know* the wealth-creating and wealth-distributing consequences of adopting cost-cutting devices ignoring all sound arguments, the anti-science, anti-machine, anti-progress agitation goes on and on.

It is becoming plainer that more than one selfish agitator is inflaming the rabble against labor-saving devices (and against private ownership thereof) in an attempt to become a dictator. We have listened to the broadcasts of our enemies and read their printed manifestos, and find that no matter what panacea they lead up to, their common theme is the old hokum about a handful of plutocrats owning eight-tenths of all the means of production—from farm lands, cattle ranches, forests and mines to all the various processing and fabricating industries; nine-tenths of the means of transportation; and seven-tenths of the agencies of distribution. *Therefore* the plutocrats adopt labor-saving machines and methods to create hordes of unemployed who scramble for scarcer jobs. *Therefore*: (1) turn over the Federal Reserve to a few hundred slick politicians elected by popular vote, or (2) give half our national income to the aged; or (3) grab all privately-owned land; or (4) steal the factories and railroads and chain stores from their legitimate owners.

Throughout these fulminations runs the thread of resentment against technological progress: the would-be Hitlers claim that *because* we have emerged from the covered-wagon age it has become possible for a few plutocrats to own nearly everything and *therefore* we must kill, jail or otherwise dispose of the plutocrats and abolish our form of government.

What the would-be dictators conceal is that "purchasing power" is not absolute but relative. Automatic devices bring *down* the cost of cars and radios and gas and oil and electric energy and processed foods and good clothes and modern houses, thereby enormously widening the markets and creating millions of *new* jobs. These jobs are in "privately-owned" establishments. What of it? Under communism or fascism there would be even fewer overlords, exercising a far more despotic power without the possibility of tripartite governmental regulation.

For proof that automaticity makes jobs by making possible mass production, look at the automobile industry.

(Our Dec. 1935 editorial—reprinted by request)

INSTRUMENTS' READERS AT WORK

No. 26—WILLIAM M. SPRINGER

Director of Research, **The BRISTOL-MYERS Co.**, Hillside, New Jersey

By M. F. BEHAR

IF you have driven to or from New York over Route 29, you have noticed the gleaming white buildings of the Bristol Myers Co. If you have flown over Hillside in a transport plane, you may have noticed that a 40 × 100-ft. portion of the main building's roof, between two penthouses, is a pond. If you were to fly close around the building in an autogyro, you would discover (1) that the pond teems with goldfish; (2) that one of the penthouses does not contain tanks and machinery but has been transformed into a conference-room type of executive office; (3) that the 40 × 120-ft. section of the top floor under the pond and

the penthouse—is an attractive research laboratory that needs but little air conditioning because it is so effectively insulated overhead. If you were the milkman you would have noticed every winter that the lights of the end penthouse are turned on at 6:30 a. m.

When we called on Charter Subscriber Springer one recent morning he had already finished half a day's work, having begun as usual at half-past six . . . Yes, dear reader, Springer is a bachelor—neither the hermit type nor the sporty type of celibate but affable, full of pep, and —as you can see in all four snapshots—younger looking than forty-four. He was born in 1893 in Brooklyn, N. Y.; graduated as chemical engineer from Columbia in 1915, and joined Bristol Myers as chemist in 1916, becoming Research Director in 1919. Though single, he has been wedded for two decades to that exacting spouse, Research, whom he serves with all his heart, soul and might—even in his hobbies: improving the instruments used in photography and meteorology; and creating new instruments for sensory measures: odor, feel, taste, hearing and sight ("organoleptic research").

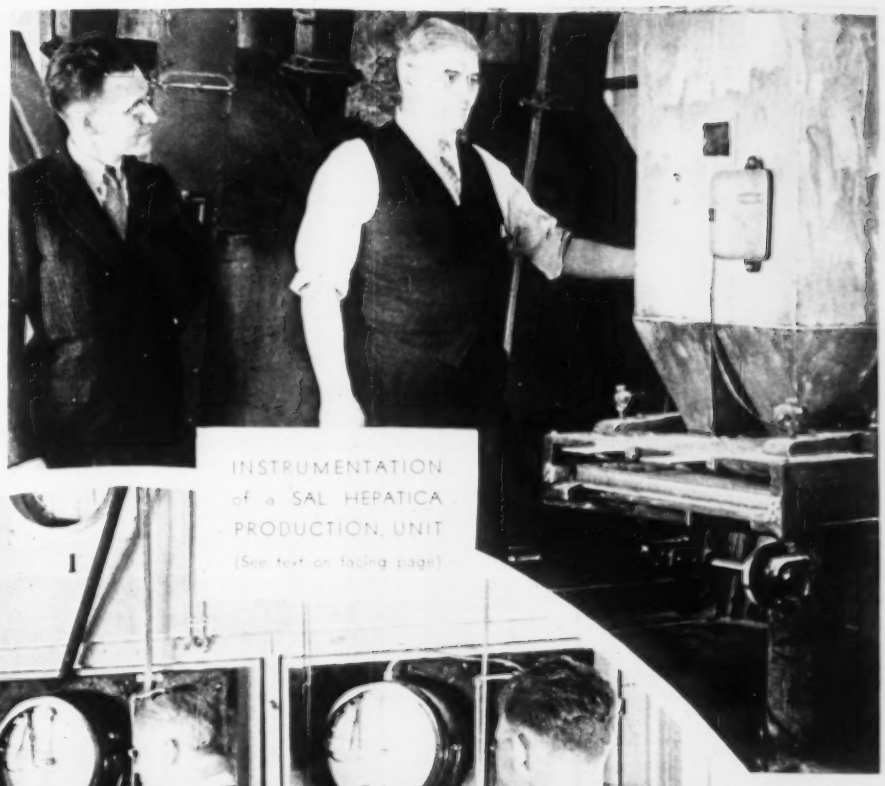
In all industries, wherever a department is headed by a constant reader of *Instruments*, his whole organization is instrument minded. Springer has (1) a research staff of three, shown with him on this page: Doctors L. A. Staib, Jr. (seated) who specializes on Sal Hepatica research; S. E. Cairncross, the Ipana Tooth Paste specialist; and Isabel Whelan whose field is cosmetic preparations; (2) two electronics and mechanism specialists: Jay Dieter and Robert Warfield; (3) two laboratory chemists; (4) two plant control men; (5) one Assistant, L. B. Dobie—shown adjusting a recorder-controller on the facing page—who has charge of Groups 3 and 4; (6) one engineer, E. P. Tibbitts, who opens up and inspects branch units in the U. S. and abroad; (7) two other workers.

As Springer took us through the model factory at Hillside we saw many obvious results of *Instruments* being read and used in all departments. Nothing is left to human judgment which can be measured or controlled automatically by methods discussed in our columns. For example, in the manufacture of Sal Hepatica as shown on the facing page (and here is where we introduce Manufacturing Superintendent L. C. Linn) all processing variables are eliminated by the use of temperature and humidity recorder-controllers and CO_2 recorders; and the compounding (top and bottom views) is done entirely automatically with such precision that the maximum variations defy ordinary analytical methods. In the manufacture of Ipana, process time controllers are also used. In the filling of tubes and jars, photoelectric and other robots perform varied functions. And of course the power house . . . but it would take many pages to do justice to the instrumentation of the Bristol-Myers Co.—several pages to describe those phases of it for which Springer is personally responsible.

SEARCH and PRODUCTION STRUMENTS at Hillside Plant

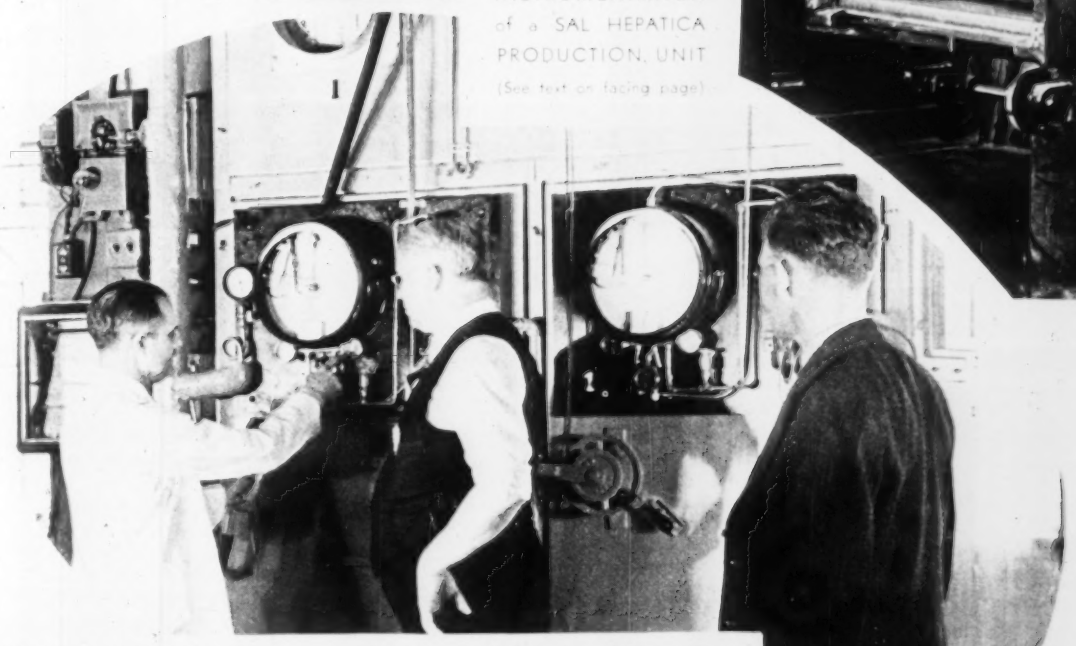
Not counting those in power house, maintenance department, etc.

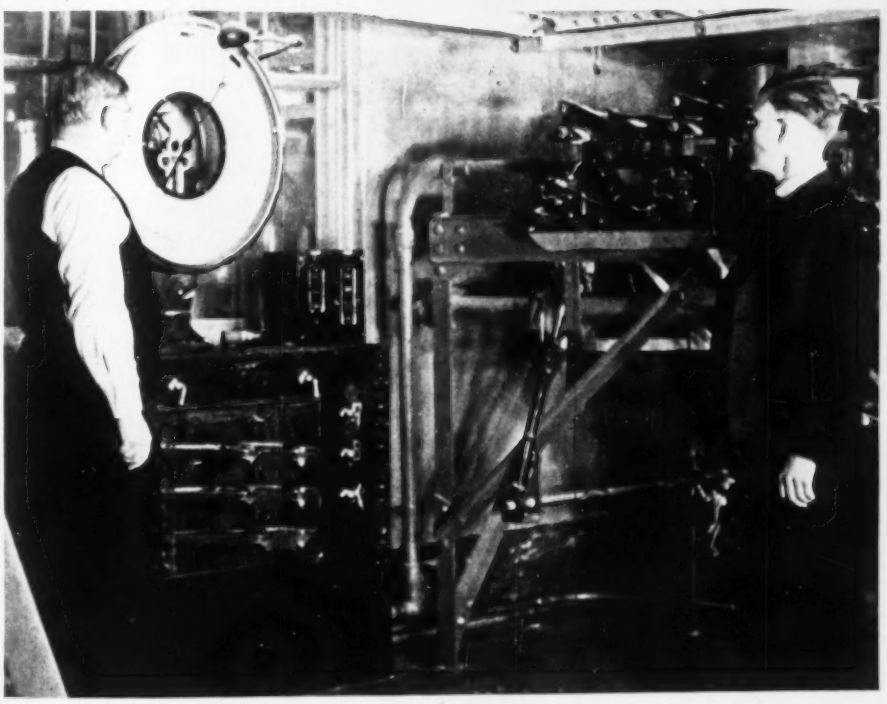
alytical balances	3
ecific gravity balance	1
andard mercury thermometers	2
ermoelectric pyrometer	1
O_2 indicator	1
ngineers' transit	1
achometers	5
op watches	6
emote water-supply tank gage	1
iscometers	2
icroscopes	2
Microscope with micrograph attachments	1
Conductivity indicator with standard cell	1
Penetrometer	1
Velometer	1
pH meter (acidimetric)	1
Ammeters (a-c. & d-c.)	11
Voltmeters (d-c.)	4
Wattmeters	3
Frequency meters	2
Power factor meter	1
Synchronism indicator	1
Radio analyzer	1



INSTRUMENTATION of a SAL HEPATICA PRODUCTION UNIT

(See text on facing page)





Bottlescopes	2
Standard gage tester (P & V)	1
Product composition analyzer	1
Tensiometer	1
Refractometer	1
Tint photometer	1
Polariscope	1
Two-pen temperature recorders	7
Single-pen temperature recorders	9
Wet- and dry-bulb recorders	4
Temperature & humidity recorder	1
Pressure & temperature recorder	1
CO_2 recorder	1
Recording wattmeters	2
Recording voltmeter	1
Indicating fluid meters	2
Recording fluid meter	1
Steam condensate meter	1
Steam flowmeter	1
Automatic weighing scales	3
Photoelectric control systems on packaging machines	11
Humidity & temperature recorder-controllers	2
Humidity & temperature controller	1
Temperature recorder-controller	1
Temperature controllers	30
Steam reduction valves	7
Feather-valve control (air pressure)	1

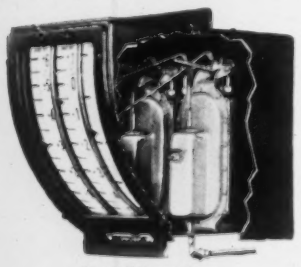
BAILEY METERS

METERS and CONTROL *for Boiler Room Service . . .*

Boiler Meters Indicate, record and integrate Steam Flow from the boiler, record Air Flow supplied for combustion and record Flue Gas Temperature. The use of this meter reduces fuel cost, lessens maintenance and outage, lowers standby costs, and adds capacity.

Bailey Boiler Meter

Multi-Pointer Gages for indicating drafts, pressures, differentials are available with any number of pointers from one to twelve. They are actuated by sturdy yet sensitive diaphragm units.



Multi-Pointer Gage

Flow Meters. For indicating, recording and integrating the flow of steam, feed water, compressed air and other fluids.

Coal Meter

Granular Material Meters For accurately measuring the flow of coal or other granular materials in gravity chutes from overhead bunkers. The total quantity of granular material is shown on a large illuminated counter which may be easily read at a distance of 50 feet.

Control Systems. Make possible the everyday operation of equipment for steam generation and utilization at test efficiencies. They are applied to the control of combustion, feed water, superheat, desuperheat and other factors.

Complete Information on any of the above Bailey products will be gladly furnished upon request.

G-7

BAILEY METER COMPANY

1041 Ivanhoe Rd., Cleveland, Ohio

NEW INSTRUMENTS

In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

When writing to manufacturers directly, please mention this department as your source of information.

Or write to Information Section, Instruments Publishing Company.

Self-balancing Potentiometer and Bridge Round-chart Recorder-controllers

"Pyromaster" line of self-balancing instruments (of which initial model was briefly reported in April issue, page 97) has been rounded out by addition of two "Free-Vane" air-operated control models — a recorder-controller (illustrated) and a recorder-controller with indicating scale and two corresponding electric-contact recorder-controller models. Measuring systems for all models are available in potentiometer or bridge circuits, with thermoelectric pyrometer or resistance thermometer elements, or with suitable primary elements for measuring speed, etc. Operating principle of self-balancing mechanism differs from motor-driven lead screw type employed in maker's "Wide Strip" line, being based on the "Self-contact Potentiometer" (*Instruments*, January 1935, pages 13-14) which this new "Pyromaster" line supersedes: Balancing is effected by a small reversible synchronous motor positioning a contact on a circular slide wire. Motor is energized through relays deriving their actuating current from a divided d-c. circuit interconnected with the galvanometer coil. Action is such that, upon galvanometer making the slightest contact in response to change in the measured emf, there flows from the d-c. supply through its winding an additional current tending to intensify the contact action, thus positively eliminating any tendency of the contacts to chatter. Auxiliary current tends to increase in value until it is sufficient to operate one control relay or the other which, beside energizing the balancing motor, opens the auxiliary circuit and leaves the galvanometer free to respond to further unbalance currents in the measuring circuit. The sliding contact thus tends to approach the balance position rapidly by a series of decreasing impulses until, when a state of balance is attained, galvanometer needle rests midway between stationary contacts and entire mechanism is dormant. Galvanometer needle travel between contacts being less than 0.001", extremely small changes in measured value cause practically instantaneous action. Pen-arm, connected to balancing mechanism, moves in small rapid steps upon change in measured value, recording changing value with negligible lag. In potentiometer models, circuit is standardized by means of high-capacity dry cell, value of current being continuously indicated on a Weston milliam-

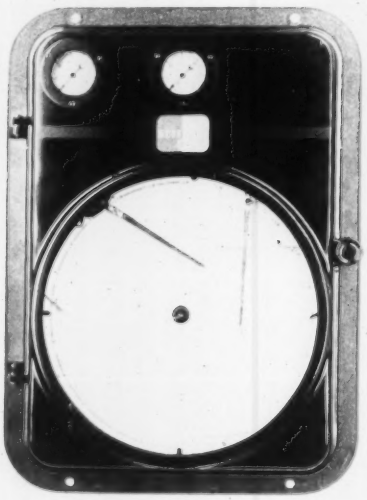


Fig. 1

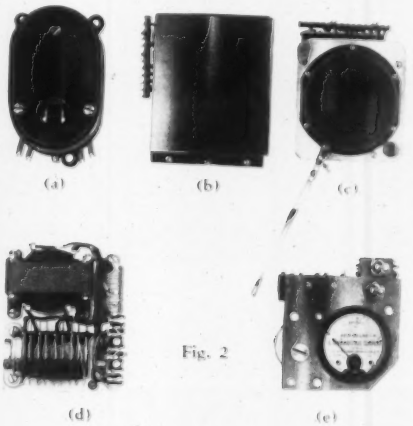
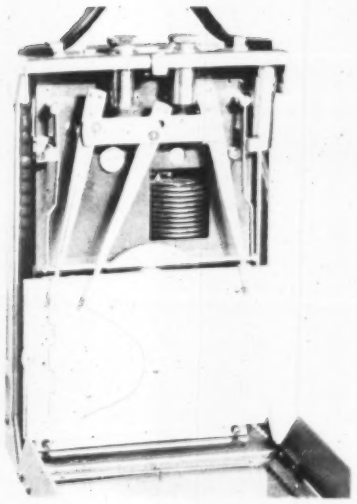


Fig. 2

meter and a fine-adjustment rheostat providing means of standardizing current. In potentiometer models for thermoelectric pyrometry, reference-junction temperature compensation is effected automatically and completely by means of a temperature-bridge circuit superimposed on potentiometer circuit. In all models, galvanometer has highly damped coil pivoted in jeweled bearings. Mechanically, principal basic design feature of Pyromaster is replaceable-unit type of assembly as shown in Fig. 2: (a) galvanometer, (b) relay, (c) slide-wire and pen-arm drive mechanism, (d) power pack and (e) standardizing unit; in addition to chart drive (not shown) of desired period. Air-operated controllers command diaphragm-motor valves; electric-contact controllers command motorized valves—both these classes of control valves being available in numerous types and sizes. *The Bristol Co., Waterbury, Conn.*



Aircraft Operation Recorder

Designed specifically for flight service, new three-pen "Flight Analyzer" comprises an aneroid-barograph type recording altimeter and two electrically-operated time-operation recorders. Center pen records air pressure on middle zone of chart which is graduated in inches of mercury; side pens record on and off durations of any pertinent navigating equipment such as radio, motor control, etc., in whose circuits they may be connected. Chart duration is ten hours. Charts are of 3" × 5" card type. Records provide analyses designed to aid operators in elimination of crashes due to hedge-hopping and other forbidden navigating tactics.—*Julien P. Friez & Sons, Inc., Baltimore & Central Ave., Baltimore, Md.*

Diaphragm-motor Lever

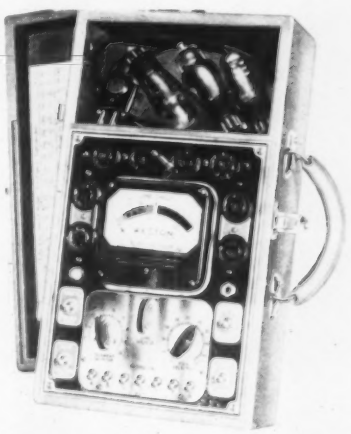
Multiplying uses to which pneumatically-operated lever motors could be put if not so restricted by non-uniform operating characteristics, new "Motosteel Evenaction Lever Motor" is reported to have been designed and constructed specifically to overcome traditional shortcomings of this type of device, giving it a much broader field of application. Features

include: (1) All-steel welded construction, same as "Motosteel Diaphragm Valve" (see *Instruments*, July 1936, page 156). (2) Operation characteristics insure uniform relation between air pressure applied to diaphragm motor and resulting lever travel throughout stroke. (3) Practically free from hysteresis: deep diaphragm with large area gives smoothly modulated action; ball bearing roller bearings guide full stroke of push rod; lever is pivoted in phosphor-bronze bushings which are alignment-reamed in same manner as automobile engine bearings. (4) A number of take-off holes throughout length of lever permit force or travel to be adjusted. (5) Power of either up-stroke or down-stroke can be increased or decreased by spring adjusting nut. (6) Lever action can be reversed by substituting another lever and transposing fixed and movable pivots. (7) Limit stops for both up-stroke and down-stroke. (8) Infinite number of mounting positions.

Three sizes: in terms of maximum damper areas which can be accurately positioned 25, 50 and 120 ft.². These damper areas may be increased appreciably when "Valv-Precisor" or "Dubl-Response Control Unit" is operated in conjunction with any of these three motors. Motor may be operated by remote manual control, by an electro-pneumatic switch, or by an air-operated controller. It also may be operated in parallel with a diaphragm valve or other pneumatic equipment, if desired.—*Taylor Instrument Companies, 95 Ames St., Rochester, N. Y.*

Tube Checker

A new radio tube checker said to have unusual operating flexibility is designed as a matched companion unit for maker's "No. 772" analyzer. The two test units may be had in a single combination carrying case, or the new "Model 773" tube checker is available with carrying case or special counter mounting. New checker features "anti-obsolescence" circuit and switching system, in which total emission tests on various types of tubes are made on a specific load basis, reflecting service conditions for (1) general type tubes, (2) battery-operated tubes, and



(3) diodes. However, selector switches and inter-electrode switches which permit all elements of each tube to be individually checked have been relocated for maximum operating convenience. The "Q" instrument scale has a color-band-marking differentiating between good and bad tubes. Operating controls and trim on the panel stand out in brilliant red and chromium against glossy black background.—*Weston Electrical Instrument Corp., 591 Frelinghuysen Ave., Newark, N. J.*

Exhaust Gas Analyzer

New "Model SR-1" is a portable self-contained outfit weighing 14 lbs., that can be used on the service floor or placed in automotive vehicle for tests under road conditions. It comprises a vacuum gage in addition to the exhaust gas indicator—both instruments having edgewise dials mounted one above the other. Gas analysis scale is graduated in "Fuel-air Ratio" and in "Combustion Efficiency" and is enlivened by five colors.—*The Potter Co., 1950 Sheridan Rd., North Chicago, Illinois.*

Let us quote you on complete

METALLIC BELLOWS

assemblies

Hydron metallic bellows are used as control elements in temperature and pressure control devices, and for liquid or gas seals on compressors and pumps. They are formed from one-piece, thin wall, metal tubing of the highest grade, expressly developed for this purpose.

The bellows have exceptional life characteristics due to the automatic testing of the tube wall in our original patented hydraulic forming process, and to the freedom from rubbing of frictional tool engagement with the thin metal wall during the forming operation.

Increasing numbers of manufacturers find it more economical and more satisfactory to have us supply the complete bellows assemblies. We have the equipment and they are pleased with the results. Let us quote you on complete bellows assemblies for your products.

We are primarily manufacturers of bellows and bellows assemblies rather than completed devices incorporating same, with the obvious intent of avoiding any competitive situation between ourselves and our customers. We do, however, produce to our customers' specifications complete devices involving our bellows.

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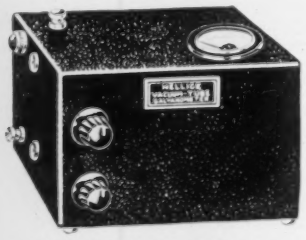


VACUUM-TUBE GALVANOMETER

This instrument is a general purpose null indicator of universal adaptability for precise measurements of oxidation-reduction potentials, streaming potentials, insulation resistance, and various types of bridge measurements.

Suitable for measuring systems of high resistance (10^{10} ohms), and those easily polarized, with the same high sensitivity (0.1 millivolt) and the same simple technique as that of ordinary systems.

HELLIGE
INCORPORATED
3702 NORTHERN BLVD. LONG ISLAND CITY, N.Y.

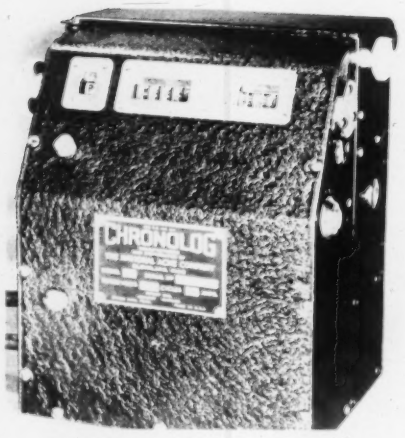


Fig. 1

Fig. 2

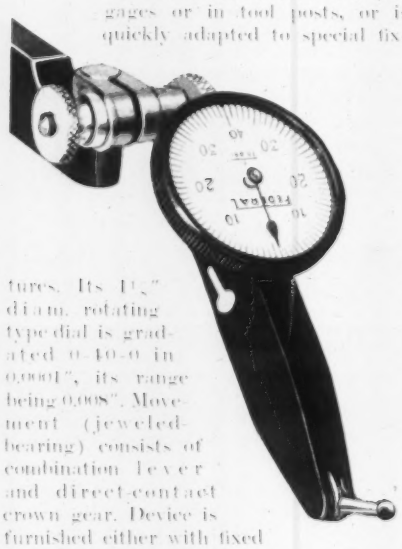
Time-operation Analyzers

Two new model "Chronologs" are announced, simplified in construction and operation, providing less detailed information than earlier models, yet furnishing all the data needed in many plants. "Model M" (Fig. 1) may be applied to any machine, process or operation. When operator begins work he turns on the "Chronolog," whereupon exact minute of start is printed on 4½" strip chart. Window at upper right shows clock time; larger window at left registers number of units produced. As soon as there is an interruption at work, operator turns knob at left to a symbol indicating reason for interruption; this is registered on chart. When production is resumed, operator pushes button on front; time of resumption is printed. Every ten minutes, "Chronolog" prints count of units produced and the time. Visits of foreman, inspector, stockman or others to the machine can be recorded. Thus, at end of day, printed record shows how many minutes machine was in operation, number and extent of all interruptions and reasons therefor. This "Chronolog" can be used as a time clock at the machine if desired. It may be adjusted so that the digit wheels give several different combinations. For example, either or both sets of digit wheels may be used for counting units or time.

New Midget "Model O Chronolog" (Fig. 2) contains only one set of digit wheels. These may be arranged to count idle time or units produced. It, too, carries chart roll which automatically prints every ten minutes, or printing may be secured at any time by inserting a card and pushing button on front. "This is believed to be the only recording counter available." — *National Acme Co., 155 East 131st St., Cleveland, Ohio.*

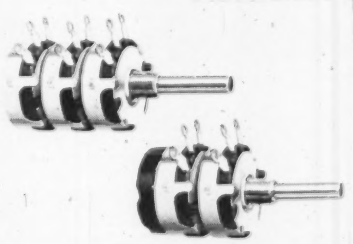
Universal-swivel Indicator

New "Model Two" Test Indicator with holding bar and universal clamp can be used in surface or height gages or in tool posts, or is quickly adapted to special fixtures. Its 1½" diam. rotating type dial is graduated 0-40-0 in 0.0001", its range being 0.008". Movement (jeweled-bearing) consists of combination lever and direct-contact crown gear. Device is furnished either with fixed contact point or with a swivel contact point. In either style, the motion of the contact point may be reversed by shifting a reversing lever. — *Federal Products Corp., 1144 Eddy St., Providence, R. I.*



Multi-unit Gang Resistors

Dual, triple and other gang controls, using as many units as desired and made up of IRC "Type C" metallized volume controls with completely shielded individual sections controlled by one shaft, are announced. Each of the individual sections can be furnished in all curves and variations of standard and special "Type C Controls" and can be ganged up with or without switch. New devices are an adaptation of the IRC metallized type filament resistance principle. In the new controls, this metallized coating is permanently bonded to a moisture-proof Bakelite base, so that base and element become integral. Contactor consists of a multi-finger spring brush, made of five phosphor-bronze spring wires, each acting independently, the effect being said to be that of "knee action." — *International Resistance Co., 401 North Broad Street, Philadelphia.*



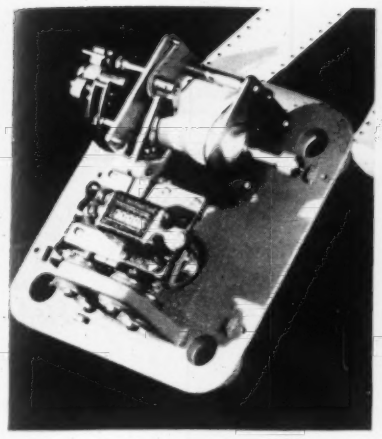


Fig. 1

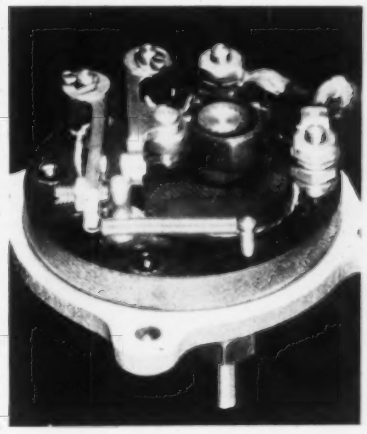


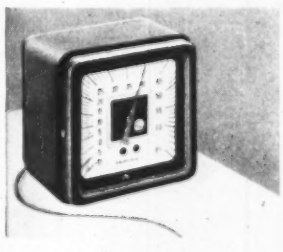
Fig. 2

Time-operation Analyzer

New "Marsto-graph" provides an abridged man-and-machine process chart in the form of a daily tape chart bearing (1) time markings in five-minute divisions easily read to one minute; (2) "on" record in the form of a succession of short cross-lines, each of which may represent one unit of work; (3) reasons for interruptions, etc., written or stamped with a small hand stamp through an opening in cover of recorder; (4) various written notations in spaces provided therefor at top or "morning" end of daily chart. "Marsto-graph" provides also, in addition to this chart record, a count of output by means of five-digit cyclometer register visible through opening in cover. "Marsto-graph" may be connected into electric circuit in various ways; may be set up near machine operator or in centralized location under eye of foreman. Installation can so be made that operator finds it impossible to manipulate Marsto-graph to build up false record. Standard tape chart travels past steel type-bar recording stamp at speed of 5 in. per hour. Therefore, record of a rapidly-operating machine, such as a punch press, is a series of cross lines stamped so close to one another that they merge into a stripe. Stoppages show as white gaps in stripe; *density* of any portion of stripe indicates *speed* of machine. Other chart speeds than 5 in. per hour are available. While recorder may be actuated by various forms of contact-making devices, makers have brought out a specially-designed rotary switch, the "Marsto-Switch" (Fig. 2) making a wiping contact and claimed to be good for millions of operations before requiring attention. *C. A. Marston Co., 500 Washington St., Braintree, Mass.*

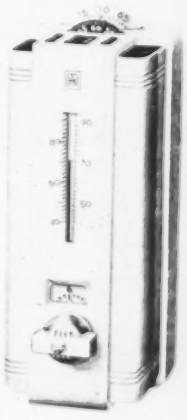
Refrigerator Thermometer

Maker's standard vapor-pressure tube system, in any of four refrigeration ranges, has been given a new case with a drum on the back for winding the capillary; the result being said to "exactly fill the bill" for refrigeration service men. Crystal being unbreakable, back-cover protecting wound capillary and bulb, movement being shock-proof and "Recalibrator" feature being provided, "Marsh Serviceman" can stand being roughly dropped into tool-box and jolted around during transportation. Rubber ring encircling case prevents marring refrigerator. Capillary armor is sufficiently slender to pass between refrigerator door and jamb without marring door. Instrument can serve also for indicating room or outdoor temperature. Available ranges (°F.): —10 to +65, —10 to +100, —20 to +40 and —20 to +65. *Jas. P. Marsh Corp., 2073 Southport Ave., Chicago, Illinois.*



Day-night Thermostat

"Da-Nite Aeratherm" combines makers' "Aeratherm" and "Time-O-Stat" into one small unit said to be "the only thermostat that offers in one instrument, manually lowered temperature, night or day; automatic return to desired temperature level whenever wanted; and the accuracy of control provided by 'Heat Acceleration'." New device has black setting wheel and winding knob both on the same shaft — eliminating necessity of arithmetical calculations. Temperature setting can be made at any point above 50 F. by moving indicator to desired lower temperature scale. Thermometer is recessed to guard against breakage. A dial lock screw prevents tampering with temperature setting, and a locking device for the cover is available. Differential is adjustable. 55 to 85° F. is day scale range; 45 to 75° F. is night scale. *Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.*



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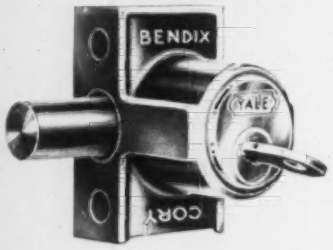

Type B-3003

The New—

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The Bendix-Cory Locking Unit is a key actuated bolt mechanism designed for use on Oil Circuit Breakers, Disconnecting Switches or other types of switchgear.

When used in conjunction with blocking segments, rods, plates or other auxiliary adapter mechanisms, an effective Interlock is created.

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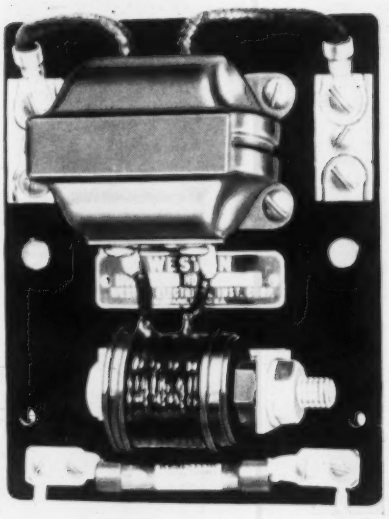


Transformer-rectifier Unit for 6-volt D-c. Supply

"Model 9980 Rectiformer" combines a 110-volt a-c. transformer and a copper-oxide rectifier, is designed primarily to provide a 6-volt d-c. power supply for power relay operation, is expected to satisfy those who formerly purchased transformers and copper-oxide rectifiers separately and assembled them for this purpose. Output of the transformer is 120 milliamps continuous, or 200 milliamps intermittent. This continuous rating permits operation of three "Model 712" power relays or one "Model 630" from each unit. Advantages of new device are said to be: (1) A protective resistor across output guards relay contacts from "kick-back" voltage. (2) Rectifier is of stable copper-oxide type. (3) Unit is designed specifically for uses in which the 6-volt circuit is opened and closed, rather than the 110-volt a-c. circuit. (4) Voltage and current ratings are such as to assure satisfactory relay operation at all times. (5) Wiring of unit is arranged to eliminate possibility of improper connections which might damage relay contacts. In addition to its use in energizing power relays, Rectiformer may serve similar d-c. requirement where filtered current is not essential. *Weston Electrical Instrument Corp., 591 Frelinghuysen Ave., Newark, N. J.*

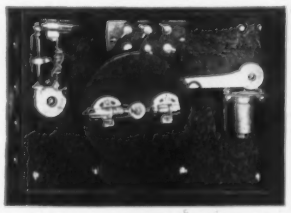
High Intensity Illuminators

Three new high-intensity light sources for microscope, optical bench, oscillograph, galvanometer, etc. Basic unit is an aluminum casting that provides housing for lamp and focusing slide for condenser. "Micolite" uses a 50-watt tungsten lamp. "Mico-Hi-Lite" is a mercury quartz lamp giving an extremely high intensity beam. "Mico-Vi-Lite," a powerful source of ultra-violet, uses this same lamp with an ultra-violet filter in place of the glass condensing lens. Micolite housing is well ventilated, may operate in any position. Other two housings are without ventilation as high-intensity mercury arc works best at a relatively high temperature. Condenser adjustment can nevertheless be made without burning the fingers. Mico-Hi-Lite and Mico-Vi-Lite use a transformer which is part of equipment and is permanently connected. These lamps can be used only on 50-60 cycles, 105-120 volts a.c.; other frequencies and voltages supplied special. Mico-Hi-Lite beam sufficiently intense to permit its use in place of a carbon arc for most projection and photomicroscopy requirements is so cool that water cells and other heat-intercepting devices are not necessary. Light source is 1 mm. wide and about 13 mm. long. Total power required about 100 watts. High pressure at which this lamp works results in a characteristic color much whiter (richer in blue and yellow) than that of a conventional mercury tube. Color filters in cells may be attached.

Mico-Vi-Lite has same operating characteristics as Mico-Hi-Lite. Red-purple Corex filter suppresses almost all visible light; intense beam of ultra-violet light produces fluorescence in substances that do not respond to the more usual ultra-violet sources. Therefore, precautions are in order when using this lamp to insure adequate protection to the eyes. *Mico Instrument Co., Cambridge, Mass.*

Pump Controls for Elevated Tank Systems

"Type A Roto-Trol" (illustrated) is a self-contained single-pump controller for elevated tank systems, operating from change in pressure on pump discharge line and not affected by pump surges caused by starting or stopping pumps. Operating principle employed is conversion of straight-line thrust of pressure-responsive bellows into rotary motion of disk, carrying one or more

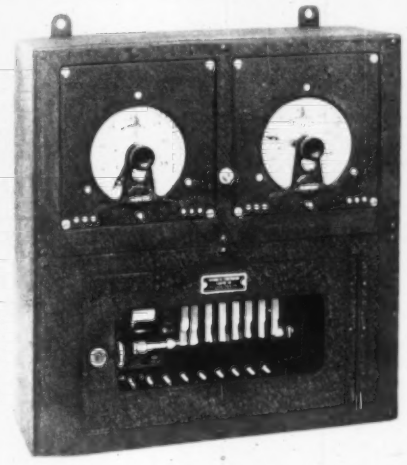


mercury switches. Pressure applied to diaphragm is counterbalanced by weighted pendulum attached to disk. Entire mechanism is mounted on steel chassis which may be removed from cabinet by removing four screws. All parts are rust-proof. Surge snubber consists in an adjustable electric timing device locking pilot circuit of starter in both open and closed positions until surges have ceased. Differential is adjustable. Micrometer setting is provided for fine adjustments of the switches. Either high or low level can be changed without disturbing the other; both can be changed without disturbing differential.

"Multi-Pump Roto-Trols" are announced also, in various combinations for providing required sequences. *Water Level Controls Co., 765 Hampden Ave., St. Paul, Minn.*

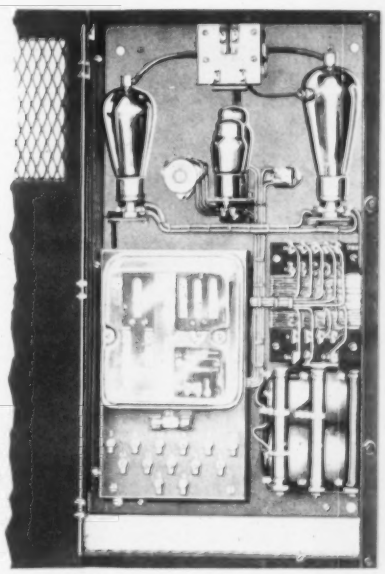
Automatic Timer for Reversal of Firing

New "Type 2700" is particularly applicable to controlled reversal of firing in coking pits, open hearths and glass melting furnaces and for the automatically-timed reversal of other heating operations. It combines two dial timers in its upper part and one cam timer in its lower half—all three being standard units in maker's line. *Operation:* at the settings shown in illustration, one end of the furnace fires for 20 minutes, and the opposite end for 20 minutes. This firing schedule continues automatically until settings are changed. Firing cycle of furnace is sum of index settings of the two dials. Firing time for either end of the furnace can be changed during operation. To prevent unauthorized change in settings, locked covers for the adjusting knobs are provided. New timer automatically functions any desired group of signals, valves and dampers to accomplish the actual reversal of the furnace. Modifications of "Type 2700" can be supplied to operate in conjunction with temperature-reversal equipment. At end of each firing period, the new timer will make, in an adjustable sequence, any desired number of contacts. Any number of operations can be started and stopped by these contacts, each action subject to independent adjustment both as to sequence and duration.—*Automatic Temperature Control Co., 37 E. Logan St., Philadelphia, Pa.*



Electronic Regulators for Alternator Voltage

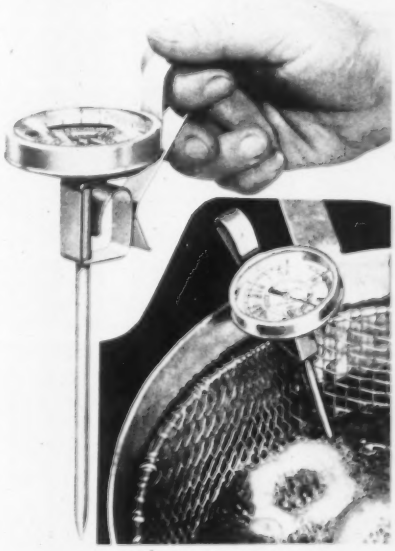
Two new automatic electronic alternator voltage regulators are announced, which perform the same functions as do other and older types of quick-response regulators. There are no moving parts in these regulators; instead of mechanical means to close contacts or change pressures an inertialess stream of electrons controls the regulating action. The regulators are controlled rectifiers deriving their power from the a-c. generator and delivering the rectified d.c. to the shunt field of the exciter in an amount which is a function of the a-c. generator potential. The corrective action of "Bulletin 5601" regulators starts within one-half cycle of change in generator voltage; that of "Bulletin 5602" regulators within one cycle. The former (illustrated) is so designed that it can be used with any known method of excitation. This regulator is now designed with an isolated supply transformer making the larger



capacities more easily arranged for switchboard mounting. The "Bulletin 5602" regulator is designed for use with one exciter only. It is said to have a wide range of application, first in small plants which have only one generating unit and second in providing individual regulators for plants operating two or more generating units in parallel. Variations of these regulators can be obtained to maintain constant voltage on 180-cycle generators, such as may be used to provide power for high-speed portable tools. Also for power factor regulation, etc. Both are said to be easy to install, require no maintenance, or replacements other than electron tubes.—*Ward Leonard Electric Co., Mount Vernon, N. Y.*

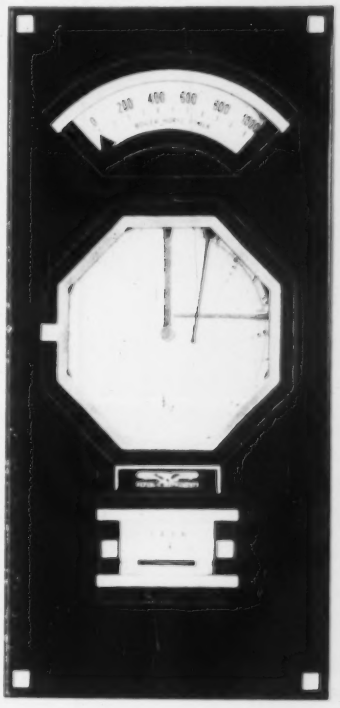
Back-stem Dial Thermometer

Brought out for general public as a housewife's cooking and roasting thermometer, this 6" stainless-steel pointed stem instrument with full-circle dial scaled 100-400° F. and detachable handle finds numerous uses in plant and laboratory. Double-coil bimetallic element assures permanency of calibration. "Pot-clip" handle furnishes convenient means of attaching instrument to utensils as shown in doughnut-cooker illustration.—*Weston Electrical Instrument Corp., 591 Frelinghuysen Ave., Newark, N. J.*



REPUBLIC FLOW METERS

- Remote Reading Type -



Republic, electrical type, flow meters are supplied for measuring the flow of all types of liquids and gases.

The indicator, recorder and integrator are remote reading and may be located any distance from the point of flow measurement. Reading instruments may be obtained in any desired combination and with related factors grouped on multiple indicators and recorders.

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The Republic Flow Meters Co., introduced the electrical type of flow meter 27 years ago and the succeeding years of engineering research have established the Republic meter as the standard for this field. This extensive experience in metering all types of fluids is available to you for the solution of any metering problem you may have. Your inquiries involve no obligation on your part.

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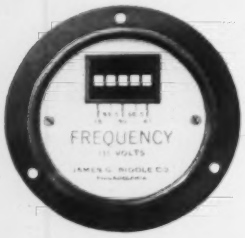

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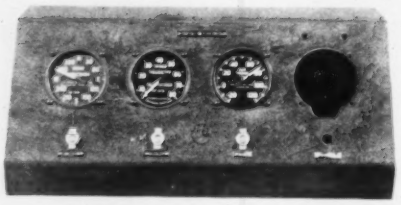


Meteorological Instrument Assemblies for Airports

"Airport Weatherman" is designation of a receiving station for three or four remote-indicating and self-contained weather instruments. Instrument dials are uniform. Combination includes wind direction, wind velocity and outdoor temperature indicating receivers; fourth instrument if desired being self-contained ground-level pressure indicator. Mounting is desk-panel form as illustrated, or radio relay rack form. *Julien P. Friez & Sons, Inc., Baltimore & Central Aves., Baltimore, Md.*

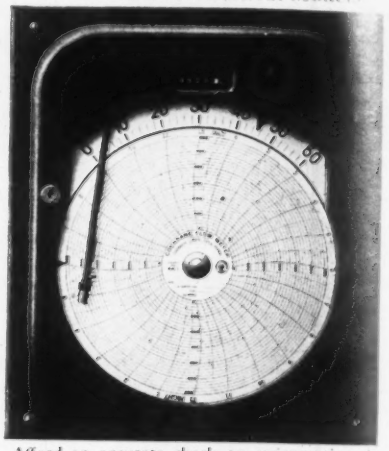
Two-inch Cathode-ray Tube

A new 2" cathode-ray tube, "Type 21-XH," has been developed for all routine operations where economy and compactness are essential without sacrificing screen area. It is of the high-vacuum type with four electrostatic deflection plates, two common, mounted in a glass envelope having a full 2" fluorescent screen. It is 7⅝" inch overall in length, with the large type of octal base. The heater voltage a.c. or d.c. is 6.3 volts making this tube interchangeable with the "913." From 300 to 600 volts may be used on the second anode. Screen is of "short persistent" type, spot color being greenish. Deflection sensitivity, depending on anode voltage, may be from 0.11 to 0.23 mm./volt d.c. *Allen B. DuMont Laboratories, Inc., 515 Valley Road, Upper Montclair, N. J.*

Automatic Volume Limiter

Developed by Bell Telephone Laboratories, "No. 110A Program Amplifier" enables broadcasting stations to increase their double effective signal level without raising their input power or increasing their licensed carrier power. In the past it has been necessary for the control operator to watch his modulation meter continuously, never daring to remove his fingers from the gain control knob. The new program amplifier automatically prevents over-modulation. It incorporates a circuit which normally amplifies program to a predetermined level. However, when input increases above a preselected level, the speech or music energy operates a volume control network in such a manner that amplification is reduced. Result is that the product at the output of the amplifier is held within desired limit, device being adjustable so that program peaks will rarely cause >100% modulation of transmitter. Basic element is a variable-loss network inserted in the program circuit and so designed that its loss is directly controlled by the instantaneous program level. Although level at input to amplifier may rise, level at its output will taper off above some preselected point, according to the way the automatic monitor has been adjusted. Thus with this device the

COCHRANE FLOWMETERS
Electric and Mechanical Models



Afford an accurate check on consumption, intake, output and variation in rate of flow of steam, water, air and miscellaneous liquids and gases.

Cochrane Flow Meters are ruggedly built and extremely sensitive to variations in recording or integrating flow. Electric model operates on the super-accurate galvanometer null principle. Measurement is possible at any distance from the pipe line, facilitating grouping of instruments on central panels. Recorders of both models are *guaranteed* accurate within ½ of 1% of absolute under full load.

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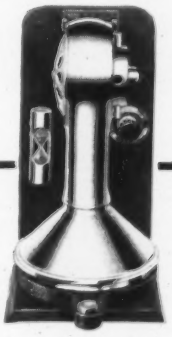

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Time required to dry most materials is one minute.

Suitable for granular—fibrous—crystalline materials in industries such as:

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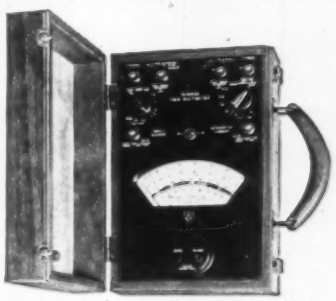

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2 milliamperes to 3 amperes
60 millivolts to 1000 volts

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The Rawson measuring instruments are the only ones having two pivot movements whose weight is lifted from jewels when clamped for transit. Electrical clamping does not accomplish this purpose.

Acknowledged leaders in development of high sensitivity meters

RAWSON Electrical Instrument Co.

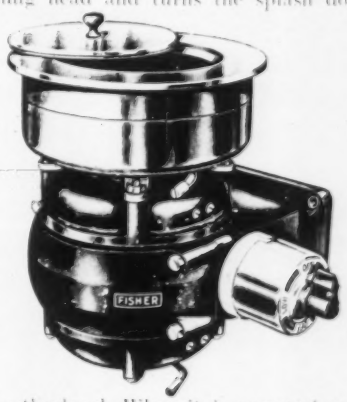
CAMBRIDGE, MASS.

New York Special Apparatus Built to Order Chicago

transmitter may be normally modulated 3 db above the level which has been considered safe with manual monitoring, and the effective coverage of the transmitter will be correspondingly increased. Whenever peaks exceed some preselected level, a light flashs so that operator may know just when and how often these peaks occur. Their too frequent occurrence indicates that general level of modulation is too high and operator is thus advised that a readjustment is necessary. *Western Electric Co., 195 Broadway, New York City.*

Metallographic Polisher

This new and "very much improved" small-size motor-driven polisher permits the use of two speeds, 1150 r.p.m. and 550 r.p.m., both slower than old models, obtained by use of a two-speed, ¼ h.p. motor directly connected, there being no rheostat employed. Each speed is full powered: placing specimen on polishing wheel does not retard it (not the case when speed reductions are obtained by rheostat). One large switch enables operator to run machine at either speed or turn it off. Polisher has a cast aluminum bowl made in two pieces: upper half surrounds and extends above polishing head and turns the splash down



into the bowl. When it is removed, polishing head is accessible so that polishing cloths can be easily changed. Lower portion has a drain and a cock for drawing off polishing liquid. An aluminum lid protects disk from dust when machine is not in use and also keeps cloth from drying out. *Fisher Scientific Co., 709 Forbes St., Pittsburgh, Pa.*

Vitreous Cover Resistors

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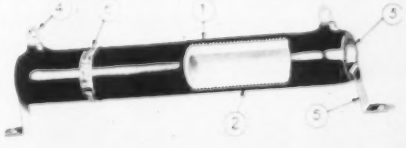
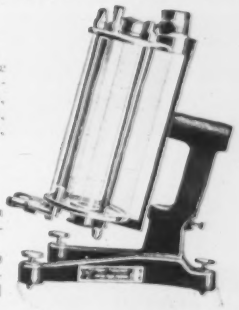


HÖPPLER VISCOSIMETER

MODEL B



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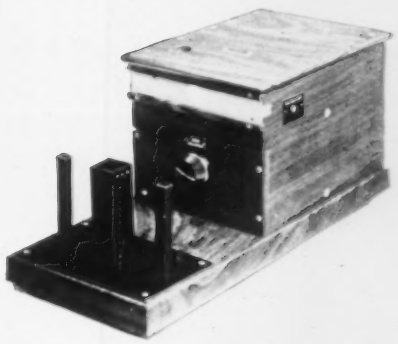

This instrument will detect the presence of one or more shorted turns in a coil regardless of the total number of turns or size of wire in the coil. Test is performed at 60 cycles using induction method which requires no electrical contact. Used by leading makers and users of coils.

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A New Method of Instrument Application

By DOUGLASS A. YOUNG
Instrument Engineer, Westinghouse Electric & Mfg. Co., Newark, N. J.

In many industries and for many years, it has been recognized that greater economy and higher efficiency are effected by the broader application of electrical instruments to individual electrically-powered apparatus. While such application programs have been under way for some time, two main drawbacks have retarded their expansion. First, the difficulty or lack of economy of initial installation. Second, the lack of complete flexibility, from both an operating and maintenance viewpoint. Under the head of economy, there must be included (a) the labor cost of an installation, (b) the effort of selecting the proper instrument, (c) the expense of adequate installation devices such as mounting details, wiring necessities, etc. Lack of flexibility includes (a) difficult substitution of individual instruments, (b) difficult maintenance, (c) the lack of a complete program of instrumentation following one initial installation.

This instrumentation problem had not been solved during the past four years, but a similar one was; during that period, rapid progress had been made in the better installation of energy meters of the watthour meter type, the solution being the detachable-from-socket principle of watthour meter application.

Taking a cue from the signal success of this principle, there has just been developed a complete range of indicating instruments, all incorporating the same detachable features as the detachable watthour meter. Standard indicating instrument mechanisms have been adapted to the same type of housings as have been used for the watthour meter. These housings have switch-blade terminals adapted to standard socket type receptacles which may be installed inexpensively in any d-c. or a-c. circuit. As may be expected, the use of high-production watthour meter housing parts permits economies in the manufacture of the complete instruments, lowering the costs not only of the instrument itself but also of the socket receptacle—apart from lower cost of installation.

FLEXIBILITY

Granting the desirability of using instruments for the better control and application of electrically-operated equipment, the question may arise: what advantage, aside from economy of installation, does the detachable instrument development offer? The answer is like that to the question: what advantages do convenience outlets offer in the home? In other words, the installation of a socket in an electrical circuit immediately opens for convenient investigation the entire operating history of that circuit, together with the complete functional story of equipment being supplied by that circuit.

(1) By plugging into the socket a test jack to which is cable-connected a portable "Industrial Analyzer" or similar kit, a complete detailed analysis may be made: load, individual line current, phase voltage, power factor, even the peak starting current of motors.

(2) When such a detailed analysis is not being made, a detachable indicating instrument may be plugged into the same socket. This instrument permits continuous observation (by the operator and by the foreman) of the condition of the equipment connected to the circuit.

(3) If it is desired to obtain a graphic analysis of the operation of a machine or other apparatus on this same circuit, one may plug in a detachable recorder which, if used for a representative period of operation, provides data of benefit in determining apparatus loading for production analysis, etc.

(4) It may be desired to plug in a total hour meter, to register the total time over any given period such as a day or week during which apparatus was actually being used.

(5) If it is desired to determine energy consumption, a watthour meter may be plugged in with little more effort than plugging in a new radio tube.

Aside from the foregoing individual transfer possibilities, designs are being developed whereby extra or temporary instruments may be inserted in the circuit *between* the socket and some *other* instrument more permanently used. For instance, it may not be convenient to remove from service, for an hour or a day, an ammeter which is being observed frequently by an operator to check the condition of his load. By the addition of an insert type of socket, the ammeter need be removed for only a brief period to insert the extra instrument.

Deserving special mention is the new approach to the problem of instrument maintenance, provided by the new detachable idea. When making periodic accuracy checks it is not necessary to "set up a standardization laboratory" at each instrument undergoing test. Instead, the instrument is removed, another quickly plugged in to take its place, while the first is taken to the department where testing and servicing facilities are available.

A LOOK AHEAD

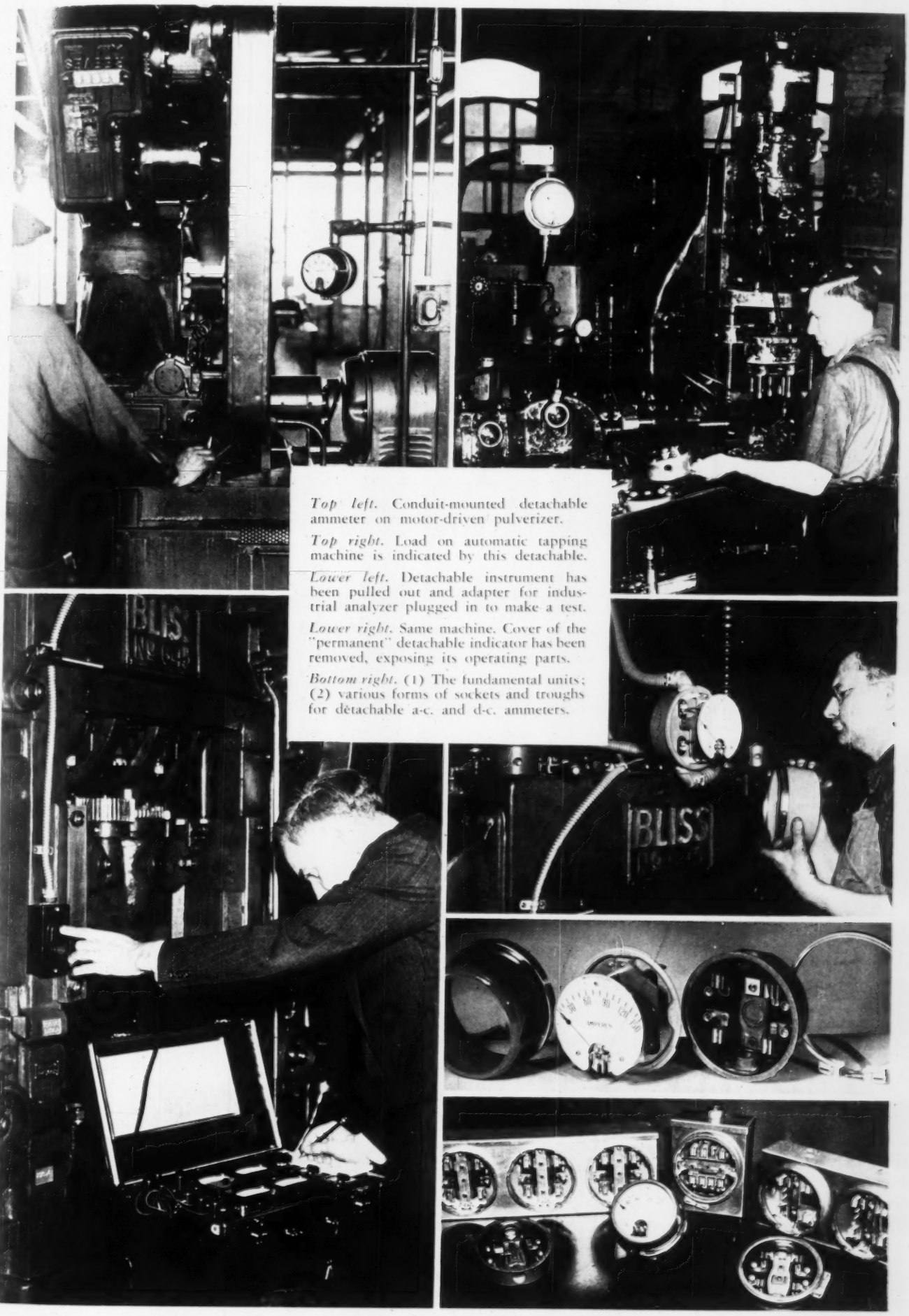
It is not intended in this article to sell the idea of using instruments in electrical circuits, as it is felt that *Instruments* readers already know the advantages thereby gained. It is only desired to bring out the new conception of meeting instrumentation problems in terms of greater flexibility and greater economy and utility as understood by the instrument man. For *Instruments* readers, here are a few details in regard to the present and future expansion of this new detachable idea.

(1) The types of instruments and sockets initially developed have been described in the "flash news" item which appeared in the June issue of *Instruments* (page 152). Additional ratings, etc., are already available, but this is not the place to list them. It is not amiss, however, to mention that all sockets may incorporate an automatic circuit-closing feature when current transformers are used. Also, if it is desired to install a socket for future use, circuit-closing blades may be inserted to provide continuity of circuit, while a cover and sealing ring prevent tampering or hazard from exposed live parts.

(2) While for the immediate present, only indicating instruments are developed with the detachable features, there will soon be made available additional units which will form the complete program for detachable electrical instrumentation. First will be the test jack, available with various combinations of switch blade terminals. By the use of this test jack, portable instruments or the more complicated recorders, such as polyphase wattmeters, may be quickly plugged into an available socket. Where it is desired to leave the portable or the recorder on the circuit for any considerable time, a standard sealing ring may be used to seal the jack into the socket, thus making the installation tamper-proof as well as free from personal hazard.

(3) There is also being developed the insert type of socket by means of which a recorder or other analyzing instrument may be inserted in the circuit between the regular socket and an indicating or other instrument for more permanent use. The insert socket may be adapted to temporary or even permanent installation of current-, voltage- or power-operated instruments. As with the test jack, by means of a standard sealing ring, the insert socket may be sealed in the socket.

(4) To permit the permanent or semi-permanent installation of recording ammeters or voltmeters, knife-blade plug-in features will be added to these instruments. Even the Total Hour Meter will be available for mounting in the standard socket.



Top left. Conduit-mounted detachable ammeter on motor-driven pulverizer.

Top right. Load on automatic tapping machine is indicated by this detachable.

Lower left. Detachable instrument has been pulled out and adapter for industrial analyzer plugged in to make a test.

Lower right. Same machine. Cover of the "permanent" detachable indicator has been removed, exposing its operating parts.

Bottom right. (1) The fundamental units; (2) various forms of sockets and troughs for detachable a-c. and d-c. ammeters.

Early Scratch Hardness Methods

Seventh instalment of "Hardness and Hardness Measurements." See page 1, Jan. 1937 issue.

By S. R. WILLIAMS
Professor of Physics, Amherst College

BRITTLENESS VS. PLASTICITY

The scratch method for measuring hardness has been applied to all kinds of solids. The results which have been obtained on brittle materials have not been consistent with those obtained on plastic materials. The reason for this lies in the fact that the scratches obtained on the two categories of materials are produced by different processes.

The Indians were able by pressing wood or bone tools against a much harder material, like flint, to shape their arrow heads into the desired forms. Their procedure was to break off the pieces of flint by applying pressure to a shoulder of the flint and shearing it off. When a diamond, or any other hard point, scratches a brittle material and abrasion occurs, much the same process goes on as in the making of arrow heads by the Indians—the scratch point is always up against a shoulder and continuously shearing off small particles of the body scratched.

On the other hand, if the solid is plastic, the particles of the surface scratched flow out from and around the scratching point. No abrasion occurs, that is, no particles are separated from the body scratched. In general it may be said that the material which scratches the other is the harder of the two. The hardness of several kinds of glass, when tested against one an other, does not follow this kind of a test. Sometimes the softer one will scratch the harder one.[1] The explanation of this is undoubtedly to be found in the fact that glass is a brittle material and when properly formed, a point of soft glass plays the part of the piece of bone in the hand of an Indian when he fashions the arrow heads from a piece of flint which is much harder.

The bits of gravel adhering to the soles of the shoes and the steel nails in the heels of the shoes which have moved over the floor of the Union Station at Washington, D. C., consist of many points working on a somewhat brittle substance and causing abrasion. If a single point is used in the scratch method and the substance scratched is brittle, the scratch method will, in general, be an abrasive one. If the scratch method is used on ductile materials it will fit more nearly into the classification known as the penetration method. Fundamentally it is a question as to whether a brittle or plastic material is being tested. In either case there is a permanent deformation. Wollaston[2] long ago drew attention to the distinction between *cutting* and *scratching*, a relation which has, unfortunately, been lost sight of by many later writers. Wollaston shows that a diamond point tears the surface irregularly unless its natural edge, which is the intersection of two curved surfaces and thus a curved line, be so held that a tangent to it lies in the plane face of the material to be cut and parallel to the direction of the diamond's motion. The curved surfaces must also be held as nearly as possible equally inclined to the plane face. With care in matters of this sort, Wollaston was able to make sapphire, ruby and quartz cut glass for a short time with a clean fissure. A fissure of only 0.005" in depth sufficed to produce a perfect fracture. In writing about the same phase of the efficiency of a cutting diamond, Babbage[3] says, "An experienced workman on whose judgment I can rely, informed me that he had seen a diamond ground with diamond powder on a cast-iron mill for three hours without its being at all worn, but that, changing its direction with reference to the grinding surface, the same edge was ground down." Recently Hoyt[4] made the suggestion that "scratching implies that the material is deformed beyond its elastic limit; in brittle materials by an amount sufficient to produce cleavage and in ductile materials, sufficient to produce plastic flow."

One point of view is from that of the cutter and the other is from that of the surface scratched. If the scratch method is to be improved, more regard must be made for these two phases than has been paid to them in the more modern devices for measuring scratch hardness. In the use of the scratch method, a warning should be sounded about the difference between body hardness and particle hardness. If the material from which a scratching point is formed is not perfectly homogeneous, there may be particles or portions harder than the main body. It is quite conceivable that in the case of a cone-shaped scratcher there might be an exceptionally hard particle at the tip of the cone. This hard particle would scratch certain substances and other cones of presumably the same material would not. Discordant results among observers would therefore arise. The earliest reference thus far found regarding the scientific measure of hardness and its variation with direction on the surface of crystals is given by Huygens.[5] He suggested that the optical properties of Iceland spar could be explained by considering a crystal as being made up of flat spheroidal molecules. At the surface of the crystals these flat spheroids were arranged like the scales of a fish. If one moves a sharp edge with the scales, it slips over them, but if against the scales it catches under the edge of the scales and the slipping is not easy. He observes this same effect in applying the scratch method to the natural surfaces of Iceland spar. The scratch method, therefore, is a means of demonstrating the way in which the crystal is built. He finds that in one direction the scratching point moves easily but in the opposite direction it does not.

Musschenbroeck[6] thought he was measuring hardness when he counted the number of blows necessary to drive a chisel through a given thickness of the material to be tested, and divided this number by the specific gravity of the material. In this fashion Musschenbroeck measured the hardness of a large number of woods and of the common metals. His metals were arranged in ascending order of hardness as follows: lead, tin, copper, Dutch silver, gold, brass and Swedish iron.

Bergman[7] calls attention to the fact that gems are usually tested by hardness factors and rates them as

[1] F. Auerbach, Ueber die Harte und Elasticitatsverhaltnisse des Glases, *Annalen der Physik und Chemie*, Vol. 53, 1894, pages 1000-1038.

[2] W. H. Wollaston, On the Cutting Diamond, *Philosophical Transactions Royal Society of London*, Vol. 106, Pt. I, 1816, pages 265-269.

[3] C. Babbage, On the Economy of Machinery and Manufactures, Charles Knight, London, 1832, pages 9-10.

[4] S. L. Hoyt, The Ball Indentation Hardness Test, *Transactions American Society for Steel Treating*, Vol. 6, 1924, pages 396-420.

[5] C. Huygens, Opera reliqua, Vol. 1, apud Janssonio Waesbergios, Amsterdam, 1728, page 70.

[6] P. van Musschenbroek, Physicae experimentales, et geometricae, de magnete, tuborum capillarium vitreorumque speculorum attractione, magnitudine terrae, cohaerentia corporum firmorum dissertationes, Lugdum Batavorum, S. Luchtmans, 1729, Chapter 10 of section, Introductio ad cohaerentiam firmorum, pages 431-672.

[7] T. O. Bergman, Physical and Chemical Essays, (English Translation) Printed for J. Murray, London, 1788-1791, pages 107-108. See chapter entitled: Of the Earth of Gems.

...ss: diamond, ruby, sapphire, topaz, genuine hya... and emerald.

"Werner[7] developed the first real scale of hardness, which has been extended by Haüy.[9] Haüy is not clear as to what he means by hardness. In comparison with Bergman's work, it is of interest to note that Haüy lists the well-known metals as follows: lead, tin, gold, silver, copper, platinum and iron or steel. Haüy's scale of hardness is limited to four groups: (1) those which scratch quartz, (2) those which scratch glass, (3) those which scratch calcspar and (4) those which do not scratch calcspar. This investigator used the term "mutual scratchibility," but the idea was certainly present in the work of Réaumur,[10] who used as an indication of hardness the motion of a substance along a bar whose hardness increased from one end to the other; the point where the material began to scratch the bar of graduated hardness would be a measure of the hardness of the substance tested. An indentation method is also ascribed to this same investigator, Réaumur, who wrote brilliantly concerning ants,[11] gave to the world a thermometric system, and who may be called the Father of hardness measurements.

MOHS' METHOD

While the scratch method has been used in studying metals and minerals, it is to Mohs[12] that we are indebted for the development of a method still in use among mineralogists. Although 112 years have passed, Mohs stated the problem of hardness testing so clearly that several pages are quoted from his text on mineralogy. Not only is there discernment of the problem but also detailed information is given for the use of the method.

"Hardness in general may be defined to be the resistance of solid minerals to the displacement of their particles. The magnitude of this resistance is their *Degree of Hardness.*"

The metallurgists think in terms of metals; here is a mineralogist thinking of hardness in terms of minerals. The physicist must insist on thinking of hardness in general terms, *i.e.*, in terms of all solids. Continuing, Mohs says,

"Hardness is a very useful property in the Natural History of the Mineral Kingdom, particularly so in its determinative part.

"Nothing is attended with greater difficulties, than the establishment of an accurate scale for the degree of hardness. It is necessary therefore to endeavor, even without an accurate scale of that kind, to become capable of ascertaining and indicating these differences, at least with a degree of accuracy and certainty sufficient for the wants of the Natural History of the Mineral Kingdom.

"The existence of differences in the degrees of hardness among the minerals is very easily discovered, by the simple experiment of scratching one of them by the other. A sharp corner of rhombohedral Quartz will produce a deep cut in the mass of rhombohedral Lime-haloide; whilst a sharp corner of the latter species does not injure the surface of the former. Hence we infer, that rhombohedral Quartz possesses a higher degree of hardness than rhombohedral Lime-haloide; and in general, that of two minerals, the harder one scratches the other, but cannot inversely be scratched by it. Some precautions, however, are necessary in drawing general inferences from these observations.

"If we proceed upon this principle, we may obtain a *Scale* for the degrees of hardness, answering in every respect the purposes of Mineralogy. This is effected by choosing a certain number of suitable minerals, of which every preceding one is scratched by that which follows it, while the latter does not scratch the former; taking care always that the intervals between every two members of the scale be not so disproportionate, as either to render its employment more difficult, or to hinder it altogether.

"The following scale possesses these properties: [See Fig. 41]

Fig. 41. A series of crystals for use in Mohs' scale of hardness
1 Talc 2 Gypsum 3 Calcite 4 Fluorite 5 Apatite
6 Orthoclase 7 Quartz 8 Topaz 9 Corundum 10 Diamond

"1. Prismatic Tale-mica, the common Tale of mineralogists, of a whitish or greenish colour.

"2. Prismatoidal Gypsum-haloide, a variety imperfectly cleavable, of an inferior degree of transparency, and not crystallized; crystals and perfectly transparent varieties being rather too soft. This degree of hardness is exactly that of Hexahedral Rock salt, which mineral therefore may be very useful, either in being immediately employed in the determination of hardness, or at least in finding out such varieties of the above-mentioned species, as exactly possess the required degree of hardness.

"3. Rhombohedral Lime-haloide. Any cleavable variety. The minerals called Brown-spar (macrotypous Lime-haloide), cannot be employed in its place, the hardness of these being considerably higher.

"4. Octahedral Fluor-haloide, Any cleavable variety.

"5. Rhombohedral Fluor-haloide. The variety from Salzberg called Asparagus-stone, possessing a conchoidal fracture. The Apatite from Saxony or Bohemia, will seldom be found to answer the purpose, though of exactly the same degree of hardness.

"6. Prismatic Feld-spar. A perfectly cleavable variety of Adularia.

"7. Rhombohedral Quartz. Limpid and transparent.

"8. Prismatic Topaz. Any simple variety.

"9. Rhombohedral Corundum. The easily cleavable variety from Bengal, called Corundum-stone.

"10. Octahedral Diamond.

"The minerals, which represent the units of this scale have been chosen among those species, which may be

[7] A. G. Werner. A Treatise on the External Characters of Fossils. Translated from the German of A. G. Werner by Thomas Weaver. Longman, Rees, Hurst and Orme, 1805, pages 192-198.

[9] R. J. Haüy. Traité de Mineralogie. Chez Louis, Paris, 1801. Vol. 1, pages 221 and 268; Vol. 3, page 348.

[10] R. A. F. Réaumur. L'art de convertir le fer forgé en acier, et l'art d'adoucir le fer fondu, ou de faire des ouvrages de fer fondu, aussi finis que de fer forgé. Michel Brunet, Paris, 1722, pages 566-587. Reprinted in part, with résumé by F. Cournot, in *Revue de Métallurgie, Mémoires,* Vol. 19, 1922, pages 447-468.

[11] R. A. F. Réaumur. The Natural History of Ants. Translated and annotated by W. M. Wheeler. Alfred Knopf, New York, 1926.

[12] F. Mohs. Grundriss der Mineralogie. Dresden, 1822. Translated by W. Haidinger. Vol. 1, pages 309-307.

most easily acquired with the necessary qualifications, excepting perhaps only rhombohedral Fluor-haloide. Yet it has been impossible to find out another which might be as useful in its place.

"The intervals between the members of the scale are not everywhere of the same magnitude. Octahedral Diamond is evidently much harder, if compared with rhombohedral Corundum, than octahedral Fluor-haloide, if compared with rhombohedral Lime-haloide. This, however, is of no consequence in the case above mentioned; for there exists no mineral of a hardness intermediate between the degrees represented by the two first of these species. But the interval between rhombohedral Fluor-haloide and prismatic Feld-spar is likewise greater than it should be. In this case it would be very desirable to have another mineral which might allow of being employed instead of rhombohedral Fluor-haloide. But in general it is very difficult to ascertain the perfect equality of the intervals between the different degrees of hardness, and on that account also it is very difficult to be obtained. Yet all these imperfections are by no means prejudicial to the useful employment of the scale.

"The degrees of hardness are expressed by means of those numbers which in the above enumeration are prefixed to them. Thus the hardness of rhombohedral Lime-haloide is = 3, that of rhombohedral Corundum = 9.

"The intervals between each two subsequent members may be divided into *ten* equal parts; and these tenths determined by estimate. It will very seldom be required to value the hardness to more or less than 0.5; but it will always be possible to proceed so far as we find it necessary to answer our purpose.

"The state of liquidity may be considered as the zero of the scale.

"If, in employing the scale, we endeavor to find the degree of hardness of a given mineral, by trying which member of the series is scratched by it, and which of them injures the surface of the given one, it will appear that the specimens employed should possess certain properties, in many cases difficult to be found. They should all have faces perfectly smooth and even, and solid angles or corners of the same form, and be equally durable.

"As to the faces, those produced by cleavage seem the most eligible, if they possess a pretty high degree of perfection. Faces of crystallization are commonly uneven or streaked; cut and polished faces, however, in many instances show a less degree of hardness than the mineral really possesses.

"It is still more difficult to obtain the corners with the constant quality which is required. Even in a determined form these are sometimes liable to be so much influenced by structure, that they give very uncertain results. In this respect, the solid angles of the tetrahedron, and those of the octahedron of octahedral Fluor-haloide, show quite different phenomena. The corners of compound varieties, in which the individuals become impalpable or disappear, such as Calcedony, Flint, and others, are commonly found very powerful, much more so than similarly formed corners of simple varieties. But if the composition is still observable, the particles very often separate in the experiment of scratching another mineral, and the corner of a compound mineral cannot produce the effect of that of the simple mineral. The application of the edges is subject to similar difficulties.

"Numerous experiments of determining the degree of hardness, by the mere scratching of one substance with the other, have completely established that this process alone is not sufficient, if we intend to make a more sure and extensive application of the characters that may be taken from hardness, than that which has hitherto been common in Mineralogy.

"But if we take several specimens of one and the same mineral and pass them over a fine file, we shall find that an equal force will everywhere produce an equal effect, provided that the parts of the mineral in contact with the file be of a similar size, so that the one does not present to the file a very sharp corner, while the other is applied to it by a broad face. It is necessary also that *the force applied in this experiment, be always the least possible.*

"Every person, however little accustomed, will experience a very marked difference, if comparatively trying in this way any two subsequent members of the above scale, and thus the difference in their hardness will be easily perceived. A short practice is sufficient for rendering these perceptions more delicate and perfect so that in a short time it is possible to determine differences in the hardness very much less than those between two subsequent members of the scale.

"Upon these observations is founded the application of the scale, the general principle of which consists in this, that the degree of hardness of the given mineral is compared with the degrees of hardness of the members of the scale, not immediately, by their mutual scratching, but mediately, *through the File*, and determined accordingly.

"The process of this determination is as follows: First we try, with a corner of the given mineral, to scratch the members of the scale, beginning from above, in order that we may not waste unnecessarily the specimens representing lower members. After having thus arrived at the first, which is distinctly scratched by the given mineral, we have recourse to the file, and compare upon it the hardness of this degree, that of the next higher degree, and of the given mineral. Care must be taken to employ specimens of each of them nearly agreeing in form and size, and also as much as possible in the quality of their angles. From the resistance these bodies oppose to the file, and from the noise occasioned by their passing over it, we argue with perfect security upon their mutual relations in respect to hardness. The experiment is repeated with all the alterations thought necessary, till we may consider ourselves arrived at a fair estimate, which is at least expressed by the number of that degree with which it has been found to agree nearest, the decimals being likewise added, if required.

"The files answering best for the purpose are fine and very hard ones. Their absolute hardness is of no consequence; hence every file will be applicable, whose hardness is in the necessary relation with that of the mineral. For it is not the hardness of the file with which we have to compare that of the minerals, but the hardness of another mineral, by the medium of the file. From this observation it appears, that the application of the file widely differs from the methods of determining the hardness of minerals which have hitherto been in use; as scratching glass, striking fire with steel, cutting with a knife, scratching with the nail, etc.

"Beside an appropriate form, there is another necessary property of the minerals to be determined, consisting in their state of purity. Neither the degree of hardness, nor that of specific gravity, can be correctly ascertained if we employ impure substances. For the same reason it would be wrong to make use of minerals which have undergone a total or even partial decomposition, and in general every circumstance which might influence the hardness, must be duly attended to, if we intend to arrive at a useful and correct result.

(Continued on Page 190)

A Method of Measuring the Non-viscous Coefficient of Friction of Lubricants

By S. KYROPOULOS and E. I. SHOBERT
Research Fellow, California Institute of Technology, formerly Dozent in the University in Goettingen
Engineering Department, Stackpole Carbon Company

INTEREST in the refinement of methods and measurements in the oil industry has led to the development of several methods for measuring the coefficient of static and dynamic friction of lubricating layers. These attempts have not been entirely successful since it has not been possible to eliminate definitely various effects such as viscous friction, dust particles, and surface irregularities of the testing mechanism.

The most common types of such measuring devices are briefly described in the book by Woog[1]. The principle most frequently used is realized in the apparatus of Deeley[2] and Herschel[3]. This consists of a horizontal plane polished disk which is lubricated with the material

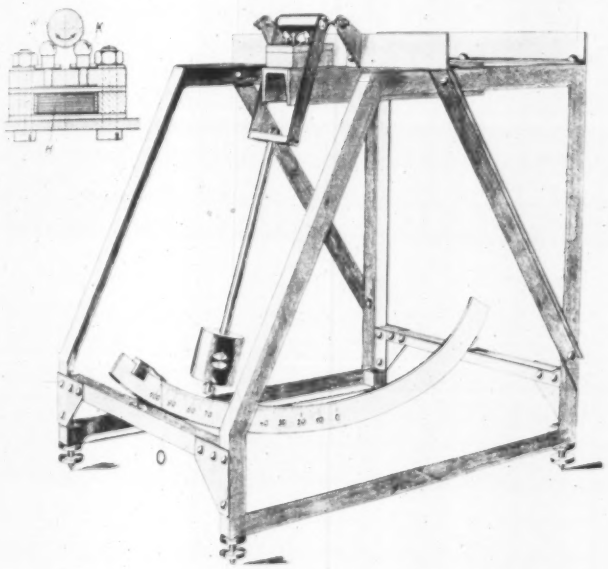


Fig. 1. Apparatus to determine the coefficient of friction of thin lubricating layers. W—Steel axle; K—Steel sphere; H—Heating element.

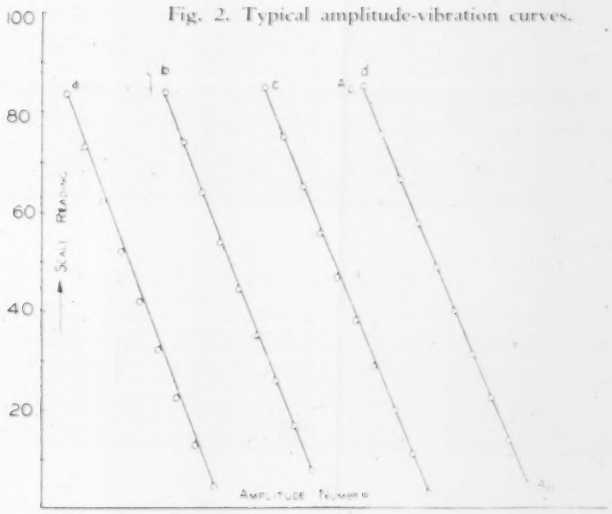
to be tested and upon which is a tripod supported by three steel balls. The tripod carries a perpendicular stem which is fastened to the support by spiral springs (Herschel). When the disk is rotated, the tripod is carried along. One of the spiral springs is wound up and the other is unwound. A pointer indicates the point at which slipping starts, and from the spring constants and the pressure, the coefficient of friction is determined. The bulletin put out by the makers of the instrument hints to the fact that the measurements sometimes become unreliable because of irregularities on the disk.

The most accurate measurements were obtained by means of a simpler device based on the same principle, a spherical slider on a plane plate, by W. B. Hardy and his co-workers on well-defined pure substances[4]. The accuracy of these measurements is demonstrated by the simple relationships found between the coefficient of friction and the chemical constitution of the substances investigated. These investigations established experimentally the basis of the connection between boundary lubrication and molecular orientation on surfaces.

Irregularities found in the measurements mentioned above call attention to the fact that, in principle, it is impossible to discover stray viscous effects, surface irregularity effects and dust effects at first sight.

As a result of frequent discussions of questions concerning the material and operation of the gyroscope compass and the Schuler pendulum, one of the authors considered the construction of an apparatus for measuring coefficients of non-viscous friction, operating either

Fig. 2. Typical amplitude-vibration curves.



on the gyroscope or on the pendulum principle. For the sake of simplicity of both method and design, a pendulum was built first, the operation of which simulates the motion of the piston rings in engines. It was considered at that time (January 1934), in accordance with the general view, that piston rings were operating under conditions of boundary lubrication for a considerable part of their path.

Fig. 1 represents the friction pendulum. The suspension consists of a ground and finely polished journal which is free to oscillate on four fixed steel balls. The support of the suspension is provided with an electric heater. The pendulum oscillates above a scale with a releasing device at one end. The ends of the journal are provided with points opposite adjustable stops on the pendulum support, which permit accurate lateral adjustment by means of a feeler gage.

The technical and experimental procedures for making measurements on lubricating materials with the pendulum are explained in another article[5]. However, con-

(Continued on Page 190)

[1] P. Woog, Contribution a l'étude du graissage. Delagrave, Paris, 1926, pages 212 et seq.
[2] T. E. Stanton, Friction. Longmans, Green, London, 1923.
[3] W. H. Herschel, Proceedings A.S.T.M., Vol. 28-II, 1928, page 687.
[4] W. B. Hardy and I. Doubleday, *Proceedings Royal Society of London*, Series A, Vol. 100, 1922, page 550.
[5] S. Kyropoulos & E. Shobert, *Ingenieur Archiv*, VII, 1936, page 222.

Errors in Cathode-ray Oscillography

Twenty-sixth part of "The Cathode-ray Oscillograph and Its Applications" being published serially in *Instruments*. This series began in July 1

By RALPH R. BATCHER

Radio engineer; cathode-ray and electronic application specialist, Hollis, L. I., N. Y.

From the standpoint of the technician who is satisfied with the indications given by ordinary electrical indicators, without regard for their inherent inaccuracies and for operational errors, a cathode-ray oscillograph is capable of giving sufficient accuracy since the more glaring errors can be avoided by the adherence to a few operating principles. The greatest drawback to precision work is the lack of a definite calibration. Of course, some of the discrepancies can be corrected for during the analysis, as by the use of calibration curves to account for any non-linearity between the deflection and the deflection potential. Such curves, however, do not compensate for non-parallel deflection plates (where the deflection constant for the second pair of plates may depend to a certain degree upon the extent of the deflection by the first pair of plates), or for pairs of plates which are not mutually perpendicular. In modern tubes neither of these conditions is found often—except in tubes that have been damaged.

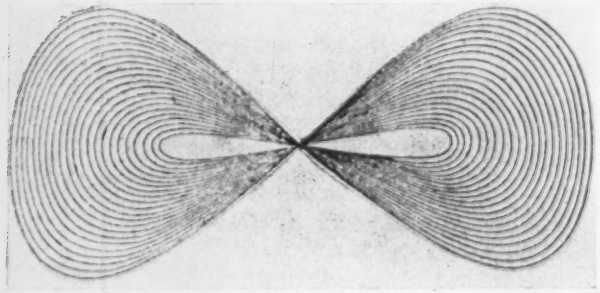


Fig. 1

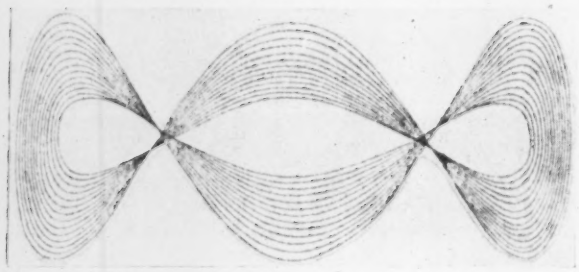


Fig. 2

In comparing any pictures obtained in the course of an experiment with standard diagrams, many variations may be expected which cannot be considered errors or distortion. A common change, for example, is that dependent upon the relative deflection amplitudes, as illustrated in Figs. 1 and 2 which show two families of curves, any one of which might appear when the frequency applied on one pair of plates is two times or three times that to the other pair.

CLASSIFICATION OF ERRORS

The major errors which may be encountered may be grouped under their principal sources, as follows:

(1) Internal effects within the cathode-ray tube.

(2) External effects associated with auxiliary equipment.

(3) Recording and reading errors.

INTERNAL SOURCES OF ERROR

In the first group a number of causes have already been reviewed: such as a non-linear deflection characteristic (page 215, Aug. 1935), screen curvature (page 338, Dec. 1935), ionization effects (the threshold error outlined page 216, Aug. 1935), and the effects of undesired fields. In addition there may be considerable confusion introduced whenever the spot is large or is unsymmetrically focused, causing errors in estimating the spot center under varying transverse velocities. The higher the speed of the spot along the trace, the less its width. After checking the focusing adjustment it is well to determine whether the size of the apparent spot is due to poor focusing or whether it is really due to a small spot moving around, as would occur in the presence of a varying magnetic field (page 303, Nov. 1935).

EXTERNAL SOURCES OF ERROR

Varying magnetic fields may be due to permanently magnetized pieces of steel nearby, to transformers, or to the deflection plates becoming magnetized. (In the last case the error is "internal.") Such fields may either move the spot away from the center of the screen, or may affect the focus in other ways. Transformer fields will either add a "tail" to the spot or cause it to move in a small circle. The diagram in this case is traced as a wavy line. If, upon swinging a horseshoe magnet nearby, the spot moves around as a waved line, it can be assumed that foreign fields are present. Otherwise, if the spot is well focused and comes to rest near the center of the screen when the deflection plates are all shorted to the anode, it can be assumed that stray fields are absent. The application of an alternating potential to either pair of plates should produce a straight line when the alternate pair is shorted. If the center of the line opens up as an ellipse, a distorting field from some apparatus operating on alternating current is present.

Insufficient filtering of the anode power supply will cause some portions of the diagram to be blurred. This condition is rather rare, because of the extreme simplicity of the filter requirements. When rectifier tubes of the gas-filled type are used anywhere in the circuit, interference oscillations are sometimes generated in the rectifier circuit which may react into the deflection circuits. Also, in many types of commercial cathode-ray tubes (such as the RCA types), the cathode is grounded to one side of the heater circuit. If the wrong cathode connection is made on the heater terminals of the mounting socket, an alternating component is introduced in the bias circuit which will cause the diagram to appear as alternate bands of dim and bright images.

Other effects, classifiable under the second group of distortion causes, are associated with the time-base oscillator equipment. In most of the commercial oscillographs now available a wide range of operating frequencies are provided. The linearity of the resulting potential variations with time may not be found at all possible adjustments within this frequency range, however. Since there usually is an overlap between frequency ranges it often is possible to find a combination of charging condenser-charging rate values which will give the desired frequency with minimum distortion (Fig. 2, Feb. 1936).

3 shows diagrams where the snap-back interval is [illegible] sufficiently rapid. These effects are common with the higher time base frequencies. The wave-form given by the time base circuit is manifestly not linear either, so that such diagrams are of doubtful value in quantitative work. It may be pointed out that the apparent horizontal axis where the snap-back appears should be disregarded. The true axis of these diagrams can always

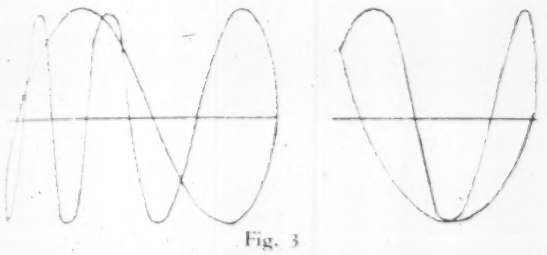


Fig. 3

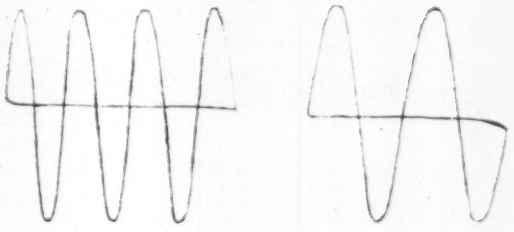


Fig. 4

be found by removing or short-circuiting the potential that produced the vertical deflection. The return sweep may actually occur either above or below this true axis, and its position is meaningless in most measurements. True undistorted oscillograms equivalent to those in Fig. 3 are shown in Fig. 4.

When the timing wave oscillator is interlocked to the wave under investigation, surges from the former may kick back into the test circuit, producing transients superposed on the measured wave. This calls for a careful manipulation of the interlock control (synchronization) after readjusting the frequency controls to give a frequency more nearly equal to the required value, and then using a much lower synchronizing potential. The presence of such interfering effects can be tested by removing the wave under investigation from the deflection amplifiers and other intermediate circuits which may be used, and noting whether the remaining deflection is a horizontal line only, with no visible vertical excursions. Better tests are made when the time base frequency is set at some value other than the frequency of the power line. If such inter-circuit interference is still noticed, using as low a value of interlock control as possible, it may be necessary to reduce the resistance of the discharge tube grid circuit so that the induced grid currents have less effect. In some cases it may be desirable to use a separate amplifier for synchronizing potentials — one that is independent of the deflection amplifier.

If the diagram appears trapezoidal in shape when an analysis would indicate that a rectangular shape should be obtained, the cause in many cases may be due to the use of too strong an interlock potential, which makes the time base be triggered off at unequal time intervals. As stated in the preceding paragraph the remedy is to remove the interlock potentials entirely and to readjust the frequency of the time base to the approximate value, and then to reapply a weaker value of the interlock potential for synchronizing purposes.

A check for the linearity of the time base is to notice whether the trace intersects the horizontal axis at equal intervals, when a frequency considerably higher than the time base frequency is applied to the vertical deflection plates.

Oscillographs of commercial makes are often provided with self-contained amplifiers, which tend to make up for the relatively low deflection sensitivity of the cathode-ray tube. A gain of 10 to 100 times is usually provided with these amplifiers. In the circuits associated with these amplifiers a condenser is usually provided as the coupling medium, so that the frequency range is thereby limited. Amplitude distortion may also be present since the plate potential swing of one or two hundred volts necessary to give the required deflection amplitude may exceed the normal characteristics of the tube used. It is a good idea to use such amplifiers only when necessary and then only after an individual calibration.

Other obscure distortional effects have manifest themselves at times. As for example in oscillographs where a common transformer supplies the operating potentials for the cathode-ray tube, the timing-wave oscillator and one or more deflection amplifiers. Here regulation difficulties may be found since the additional drain taken by certain of these loads at frequent intervals may alter the deflection sensitivity of the cathode-ray tube, or the amplification of the amplifiers.

The somewhat variable current drain due to the time base oscillator will in some cases affect the other circuits to cause false indications. This effect would be more noticeable if it were not for the fact that such surges occur at the extreme edges of the oscillogram and the amplifiers usually have a chance to recover before a great deal of the next transversal takes place. In some circuits the time base oscillator is operating at all times that the oscillograph is in use — whether it is used to supply the horizontal deflection or not — due to the fact that its tubes operate from the same power supply as the rest of the circuit. In this case false deflections may be apparent each time the discharge tube operates.

Another source of distortion is due to the effects introduced into associated circuits by the charges collected by the deflection plates themselves. These effects have been reviewed in the Aug. 1935 instalment.

ERRORS OF READING

As to the personal errors in reading the diagrams on the oscillograph, those due to incorrectly establishing the location of the true axes, and to marking inaccurate distances along the screen, are the most important. These have been discussed in previous sections. Possibly the greatest of all inaccuracies are due to the inevitable shifting of the diagram when some types of measurements are being made, due to changes in the circuit under test, or to shifts in the time base frequency. While these shifts are troublesome in some cases, yet in other tests they provide a visible average or weighted answer which may be of greater value than a single specimen which, by the laws of probability, might be close to the average or might be close to the maximum error.

To be continued

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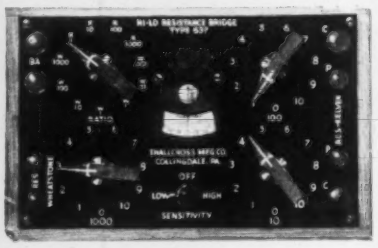

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PROBLEMS — SOLUTIONS — DISCUSSIONS

MAY PROBLEM (No. 7)

DETERMINING PUMP EFFICIENCY

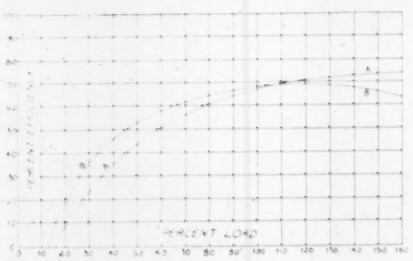
From a large phosphate company: "We desire meters integrating (in ft.-lb.-hrs.) the discharge of sand pumps in mining pits. Max. vacuum on suction side is under 28"; max. head on discharge side is under 200 ft. Percent of solids varies so much that load fluctuates from ¼ load to heavy overload (quite unlike test-block where a pump handling clear water runs at constant load and speed). We easily meter the electrical energy consumption, but desire to meter simultaneously the work actually performed, in order to obtain significant data."

85 PRIZE SOLUTION

By RICHARD P. BALLOU
MILWAUKEE, WIS.

When it is not feasible to measure directly the output from any electrical combination, it may be determined by multiplying the measured electrical input by the efficiency. Where wide load fluctuations cause corresponding variations in efficiency, an average value must be used. This value is not difficult to obtain.

First, an overall efficiency curve of the system must be prepared. It sometimes is possible to compute this from known constants of the machines, but it generally is necessary to determine it by test. A direct-reading wattmeter is the essential instrument, and the local electric company will probably be willing to loan one of the proper capacity, and send out a man to connect it into the circuit and assist in taking the data. When the system is operating at a fairly constant load, the wattmeter reading is recorded and the output is collected over an accurately measured interval such as one minute. The output



is then weighed, counted, or otherwise evaluated, and with a few simple computations the efficiency curve can be plotted from a few such tests.

Two illustrative efficiency curves are shown. However, it generally is more convenient to plot efficiency against kilowatts directly.

The use of the curve depends on the convenient fact that the efficiency *vs.* kilowatts is almost identical with the average efficiency *vs.* kilowatt-hours per hour. Therefore, to determine the output at the end of the day it is only necessary to know the number of kilowatt-hours consumed, and the length of time involved. If the machine does not run a specified number of hours each day, a self-starting electric clock connected on the load side of the motor controller will show the number of hours it has run.

Suppose a machine has run 5½ hours during the day and the watthour meter shows 77 kwh. consumed. This is an average of 13 kwh. per hour. From the curve, find the efficiency corresponding to this consumption and multiply it by 77. This is the useful output in electrical units, and can be converted to gallons, bushels, pounds, or other practical units, by multiplying by a constant easily found from the data used in preparing the efficiency curve.

This method is subject to a small error, depending on the range covered and the shape of the efficiency curve. A competent electrical engineer can analyze the curve and determine the maximum error possible. In the case of the curves shown, if the machine operates equal lengths of time at 90% load and at 160% load, the error occasioned by using the average value (90%), is, with Curve *A*, less than 3% and with Curve *B*, 12%. This is an extreme case. If the load is more evenly distributed, the error is less.

If the efficiency curve is of the general type of Curve *B*, and the error is too big, the error can be reduced by using two watthour meters and clocks, and obtaining two outputs independently and adding them. In this case the current coils of the meters are connected in series, while the voltage is switched between them by a series relay. The relay is operated by current corresponding approximately to the load giving maximum efficiency, and even the stability of its calibration is not important. Effectively, this divides Curve *B* into two curves of the general form of Curve *A*.

This method of determining output is a general one, in no wise restricted to pumps. It may be much more convenient than attempting to measure a bulky discharge directly.

85 PRIZE SOLUTION

By EMIL J. SCHEIBER
MARTINEZ, CALIF.

This solution requires two instruments: first, a recording pressure gage equipped with two pens, one pen recording absolute discharge pressure and the other recording absolute inlet pressure of the pump. For use in the following equations they are assumed to measure in pounds per square inch.

The second instrument to be a recording flowmeter used with a Pitot tube, as either a weir or orifice plate give erroneous readings due to the solids in the flow. Readings to be in gallons per minute.

From the readings obtained from the above instruments

$$\text{Hydraulic hp.} = \frac{\text{g.p.m.} \times (P_d - P_s)}{1715}$$

which is the pump output. The electric

measured in kw. could be converted to hp. = kw. 0.746

overall efficiency

$$= \frac{1.35 \times 10^{-4} \text{ (g.p.m.)} (P_d - P_s)}{\text{kw.}}$$

From motor characteristic curves the motor efficiency may be obtained for any load or electrical input.

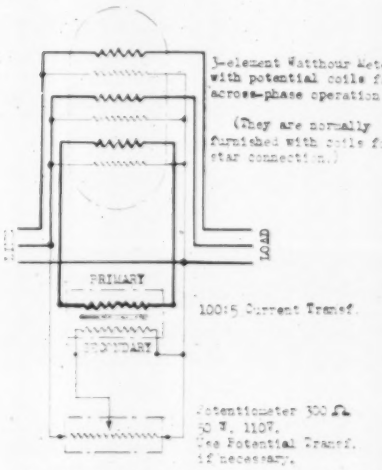
$$\text{Pump efficiency} = \frac{\text{overall efficiency}}{\text{motor efficiency}}$$

After these instruments in conjunction with a kilowattmeter have been installed, a set of curves could be worked out plotting kw. input *vs.* hydraulic output for one particular unit—eliminating the flowmeter and pressure gages, retaining only the kilowattmeter and the curves worked out, to obtain the output for that particular motor and pump unit.

$5 PRIZE SOLUTION
By R. H. LONG
OAKLAND, CALIF.

The simplest and cheapest method of measuring the power required to lift the solid matter handled by the pump would be to install a total time meter similar to the Westinghouse Style 879999 and connect it to one phase of the motor circuit through the proper potential transformer so that it will record the total number of hours the motor operates. Next measure the wattage required to operate the pump handling water only. This figure in kw. multiplied by the reading of the total time meter in hours will represent the kwh. for handling water only over that period of time, and the difference between this figure and the actual reading of the watthour meter will represent the number of kwh. that was used for handling solid matter. Kilowatt-hours is directly convertible into foot-pound-hours. This would, of course, be accurate under the one set of head conditions only.

Another more satisfactory way if pumping conditions change often would be to install a three-element three-phase watthour meter connected according to the diagram herewith. With the pump handling water only, adjust the potentiometer so that the single-phase phantom element balances the torque of the


3-element Watthour Meter with potential coils for across-phase operation
(They are normally furnished with coils for star connection.)
PRIMARY
100:5 Current Transf.
Potentiometer 300 Ω 50 W. 1107. Use Potential Transf. if necessary.

Connect single-phase phantom to oppose 3-phase element.
Adjust Potentiometer so that watthour meter "stands still" when pump is handling water only
Watthour meter then indicates only the power used in handling the material of higher specific gravity than water

three-phase element causing the meter to stand still. This meter will then record only the kwh. consumption used in handling the solid matter through the pump. The efficiency of the pump and motor will vary so little with variations in the amount of solid matter handled that this will give a satisfactorily accurate indication of the actual power consumed in handling the solid matter. If the total lift in feet is measured, the actual weight of the solid matter can be computed.

Three solutions received; three accepted by us for publication, but not one satisfied completely the Superintendent of the phosphate company, who writes us: "Solutions are entirely theoretical and will require a great deal of time and study before any practical statement can be made. Thanks for your interest."

We hope that within a few months this Superintendent will kindly write an illustrated technical article for Instruments, *describing the solution finally put into practice.* MFH.

Problem No. 9 Subject Index 2.08

MEASURING FURNACE HUMIDITY

From the Chief Engineer of a mining-milling-refining company: "We have a furnace in which the temperature ranges from 650° to 1600° and wish to measure the humidity in the furnace atmosphere. We wish at least to determine the humidity from time to time by a sampling method, but it would be better if we could obtain a continuous indication and a chart record." (Inquiry dated June 23, 1937)

Editor's comments: (1) Pressure no doubt is atmospheric or close thereto. (2) Solutions must take into account the probability that furnace atmosphere includes—in variable proportions—constituents which may affect the readings of the measuring device as would water vapor. Therefore, solutions should include discussions of sources of error. In fact, "discussions" rather than "solutions" are what we expect readers to send in. But if any reader knows a real solution, let him by all means send it in! (3) Please state in your solution or discussion whether the method you propose will give the water vapor by weight or by volume—and also whether actual or reduced to normal temperature.

Five dollars will be paid for every solution (or critical discussion clearly pointing the way to a solution) which is accepted for publication. Address Instrumentation Forum, 1121 Wolfendale St., Pittsburgh, Pa. Type double-space, on one side of paper. Draw diagram in black ink on separate sheet. Mail before August 15. Solutions and discussions accepted will appear in Sept. 1937 issue.

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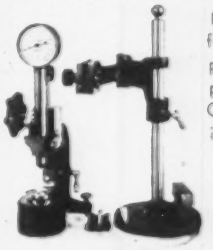

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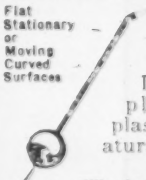

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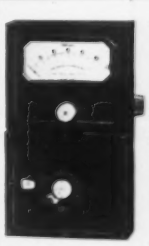

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EARLY SCRATCH HARDNESS METHODS

Concluded from page 184

"Minerals that cleave with particular facility in only one direction, very often show a less degree of hardness upon the perfect face of cleavage than in other directions. Prismatic Disthene-spar sometimes is scratched by octahedral Fluor haloide upon the eminent face of cleavage, whilst an angle of the very same individual scratches not only rhombohedral Fluor haloide, but even sometimes prismatic Feld spar. If we intend to determine a mineral of this description by the help of the Characteristic, it will be the best plan to take a mean term between the two degrees measured, or rather to keep nearer to the higher one. It would be wrong to receive them into a scale of hardness, like the preceding one, since this would betray a want of acquaintance with the scale itself, and with its employment.

"Supposing all the precautions necessary in determining the degrees of hardness to have been taken, and the circumstances well attended to, which might have exercised some influence; we find that those individuals which belong to one and the same species, admirably agree with each other in respect to this property; and that deviations from an exact coincidence, if they happen to occur, do not take place *per saltum*, but that they are joined with each other by intermediate members. These members produce a series, in most cases between very narrow limits. This observation seems to be contradicted by the authority of several mineralogical works. But there are indeed few subjects with regard to the properties of minerals, which have been treated with more indifference or even carelessness than their hardness and on this account little or no credit is due to what most of the mineralogical works contain of its indications.

"Kirwan, De La Metherie and Romé De l'Isle have each endeavoured to construct scales of hardness. A comparative table of the hardness of different substances is contained in the works of Haüy. A glance at them will suffice for enabling us to form an idea of their applicability."

Some writers describe the method developed by Mohs as being really the work of Haüy. Mohs' own reference to Haüy may be taken as stating the situation. Also Haüy had only four steps in his scale of hardness and they were limited by calcite, glass and quartz. Mohs increased his steps to 10 and although later mineralogists have inserted other steps since his day, Mohs' scale has in general been retained. In studying Mohs' method, one is impressed with the care he employed in selecting his standards and in the shrewd idea of having those minerals easily obtainable. The mineralogist has his tester already prepared for him. He does not need to have some elaborate machine set up for the purpose. Mohs also developed the use of the file for fractionating his steps of hardness. The file test is distinctly an abrasive method and was evidently in use long before Mohs' application. Thus far there is little to be found on the historical side concerning the use of the file for hardness testing. Among mechanicians today the file is a common tool for measuring relative hardnesses. Auerbach points out that it is well that Mohs' scale has remained as Mohs developed it, because to reduce some of the larger steps in the scale would have been productive of error rather than of increased accuracy. Whatever may be said against Mohs' scale of hardness, it has served a most useful purpose for the mineralogist and will continue to do so until some method more simple and effective is devised. Fig. 11 shows a modern collection of Mohs' crystals arranged for hardness testing.

To be continued

A NEW LUBRICANT TEST METHOD

Concluded from page 185

sidering the three main objections to other methods of measuring boundary friction, we may show wherein these are overcome with this method.

Stray viscous effects are recognized immediately by the shape of the amptitude-vibration number curves shown in Fig. 2. With pure non-viscous friction the curve should be a straight line and when viscous friction is present, the deviation is similar to that shown in (a). It is known that the coefficient of viscous friction decreases greatly with increase in temperature, and that the coefficient of non-viscous friction is independent of temperature over a wide range. By heating the journal and the steel spheres shown in Fig. 1 with the electric heater, it is possible to eliminate the viscous effect if it is present, or rather, to make this effect negligible. Fig. 2 gives a set of curves characteristic of a group of measurements made as the temperature is slowly increased. From the slope of the line (d) and the constants of the pendulum the coefficient of friction is calculated.

The presence of surface irregularities which would change the value of the coefficient of friction is eliminated by a wearing-in of the operating surfaces. After the initial wear-in of the operating surface it has been found that with any particular material the value of the coefficient of boundary friction does not change, even though, as the pendulum is used, the steel spheres may show visible flat spots. In other words, it has been found that throughout a great number of measurements and after several months of continuous operation, the values for a particular material remain constant if the material itself remains constant. Thus, by proper preparation and use of the pendulum, the effects usually caused by surface irregularities do not occur.

Dust particles and foreign bodies may present a serious problem with the usual methods. With this method, however, the presence of dust and other foreign materials which are discontinuities in the material being measured is shown immediately by the shape of the curve obtained by plotting the amplitude against the vibration number. The presence of any discontinuity will result in a discontinuity in this curve, and then the measurement must be repeated more carefully to eliminate the foreign material.

The most important application of this new method should be in the oil industry where, because of its accuracy and the ease with which it may be operated, it should be used for routine tests where present methods are not accurate enough.

In addition to routine tests on commercial oils, the pendulum has an important application in any work on testing the effects of additions to motor oils intended to improve friction characteristics. Since most of these additions depend for their effectiveness on the adsorption of these materials on surfaces, this method will give the actual values of this boundary friction without interference of stray viscous effects which would mask results.

Another valuable application for this new method is in the physics and chemistry of adsorption. Since the pendulum measures an effect which according to present theory depends only upon the adsorbed layers on the two surfaces, *i.e.*, the journal and the steel spheres, it is possible to learn much concerning the adsorption of various materials on the surfaces which are built into the pendulum.

We wish to thank Professors Prandtl and Schuh of Göttingen, for the interest which they have shown in this work.

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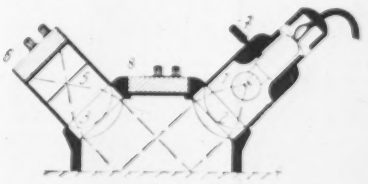

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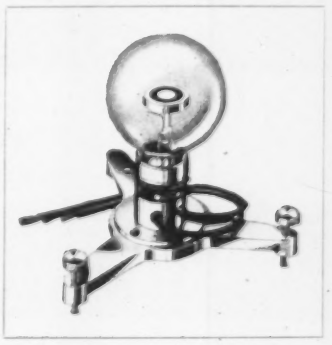

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